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Our Killer Galaxy's Violent Past

Inside a Giant Star Factory

- See the Asteroid Toutatis Whiz Past Earth
- How to Choose a Star Atlas

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12"
MEADE LX200 EMC
10"
MEADE LX200 EMC
7"
MEADE LX200 EMC
8"
MEADE LX200 EMC
Meade
MEADE LX200

MEA

LX200

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models ***combined***. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of over 64,350 objects in the onboard database, *to a precision of one arc-minute or better.*
- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an auto cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); complete operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

LX50

Advanced technology at the most affordable prices *ever*.

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y, only	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

LX50 models shown with optional Field Tripod.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Quick 2-star alignment. ■ Large 32-character, red-backlighted display. ■ 4-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.

Write, call, or fax Meade Instruments for your free copy of the 94-page Meade 1997 General Catalog. Prices shown are suggested U.S. mail-order retail prices.

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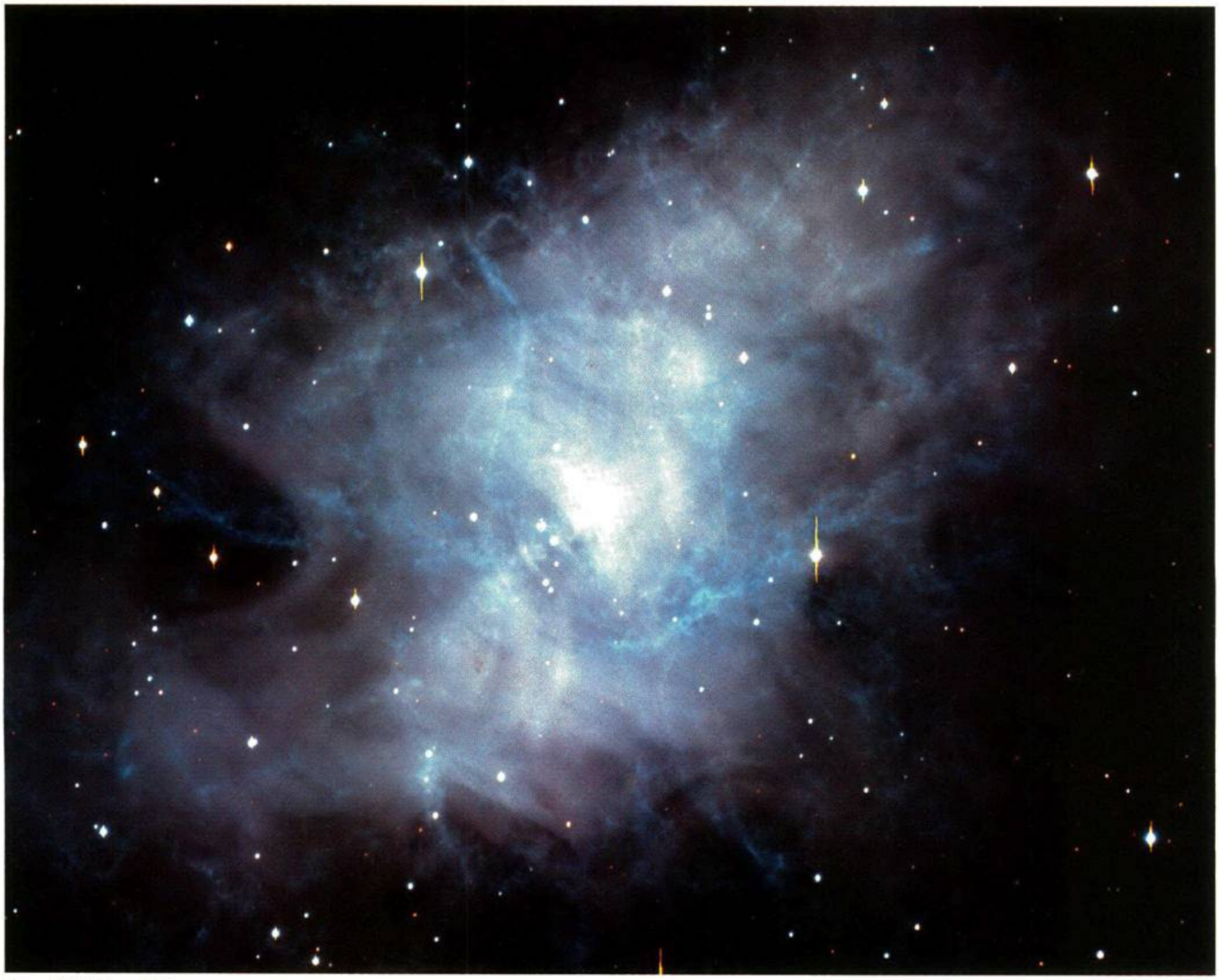

Jay Gallagher and Eric Wilcots (Univ. of Wisconsin)

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One Hot Stellar Nursery

Lacy tendrils of gas and dust swirl in intricate patterns around the blazing stars at the heart of the giant emission nebula NGC 604. Hubble shows unprecedented detail in this stellar birthplace, located in the neighboring Pinwheel Galaxy. *Patti A. Kurtz.*

Cover Photo
Hui Yang (Univ. of Illinois), Jeff Hester (Arizona State Univ.) and NASA

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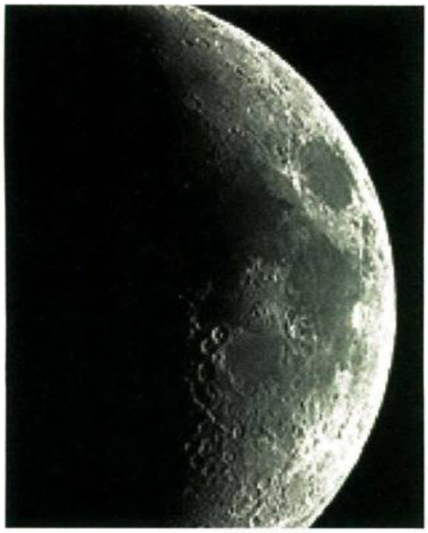
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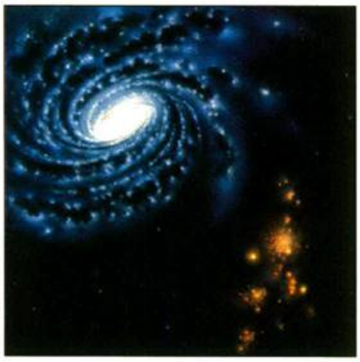
BEHIND THE SCENES

Our Killer Galaxy

Romanticism has thrived in western culture, coming into full fashion at the turn of the 19th century. One chief tenet of the romantic school held that the natural world was benevolent, that animals and people left to themselves in an untamed and uncivilized landscape would become kinder and gentler — harmonious in fact. That's the period in which people painted a lot of lions and lambs lying about in a countryside that vaguely resembled rural England (where most of them were painted.)


Mark Paternostro

Our killer Galaxy at work.

As Charles Darwin's theories on survival of the fittest took hold, this theme in the arts took a steady nosedive. Since that time — even in the arts — nature has mostly been seen as a realm filled with threat and danger. From H. G. Wells to the X-Files, the myth of biological harmony dissipates. Not only do we all now know for sure — via the Discovery Channel — that animals eat each other in the wild, we know that most cannot be tamed. And neither can Earth's physical character. The weather patterns on our planet provide for endless entertainment — and for endless destruction. Hurricanes, tornadoes, big freezes, and floods kill people. In addition, volcanos erupt, earthquakes shake us, and fatal lightning bolts strike — all taking us mostly by surprise.

Likewise our bigger home, the universe, is filled with surprise. We are provided with many partial views of one natural catastrophic event after another — comets colliding with planets and stars exploding. And as we recognize more about the objects in our own world, we see signs of past life on Mars and begin to attribute huge changes in Earth's biological patterns to collisions with meteors or asteroids. The nature of the universe is wild and dangerous. There's no reason at all why our bigger home should behave differently than the solid part on which we stand.

The wildest part of nature (and certainly the most mysterious) may reside beyond Earth's gravitational influence. For us, the true wilderness is to be seen in our night sky — in our home galaxy and beyond. In this issue of ASTRONOMY, science writer Ken Croswell describes the dangers that lurk there. His tale is one of death for a dwarf galaxy in the constellation Sagittarius. On page 36, look for "To Kill a Galaxy," which portrays our home Galaxy, the giant Milky Way, as a killer gobbling up smaller galaxies that get too close. Croswell warns that even the bigger, tougher Magellanic Clouds are beginning to succumb to the Milky Way's pull. Our Galaxy has a Magellanic tail well in tow.

Except for a bit of space debris and some very local light pollution, humans have apparently affected the universe very little. We identify the movers and shakers of the universe, and its occasional bombshells, but we know just enough to expect the unexpected. At ASTRONOMY, we make it our business to guide you through the mysteries of the universe. Stay tuned.

Bonnie Gordon

Bonnie Gordon
Editor

ASTRONOMY®

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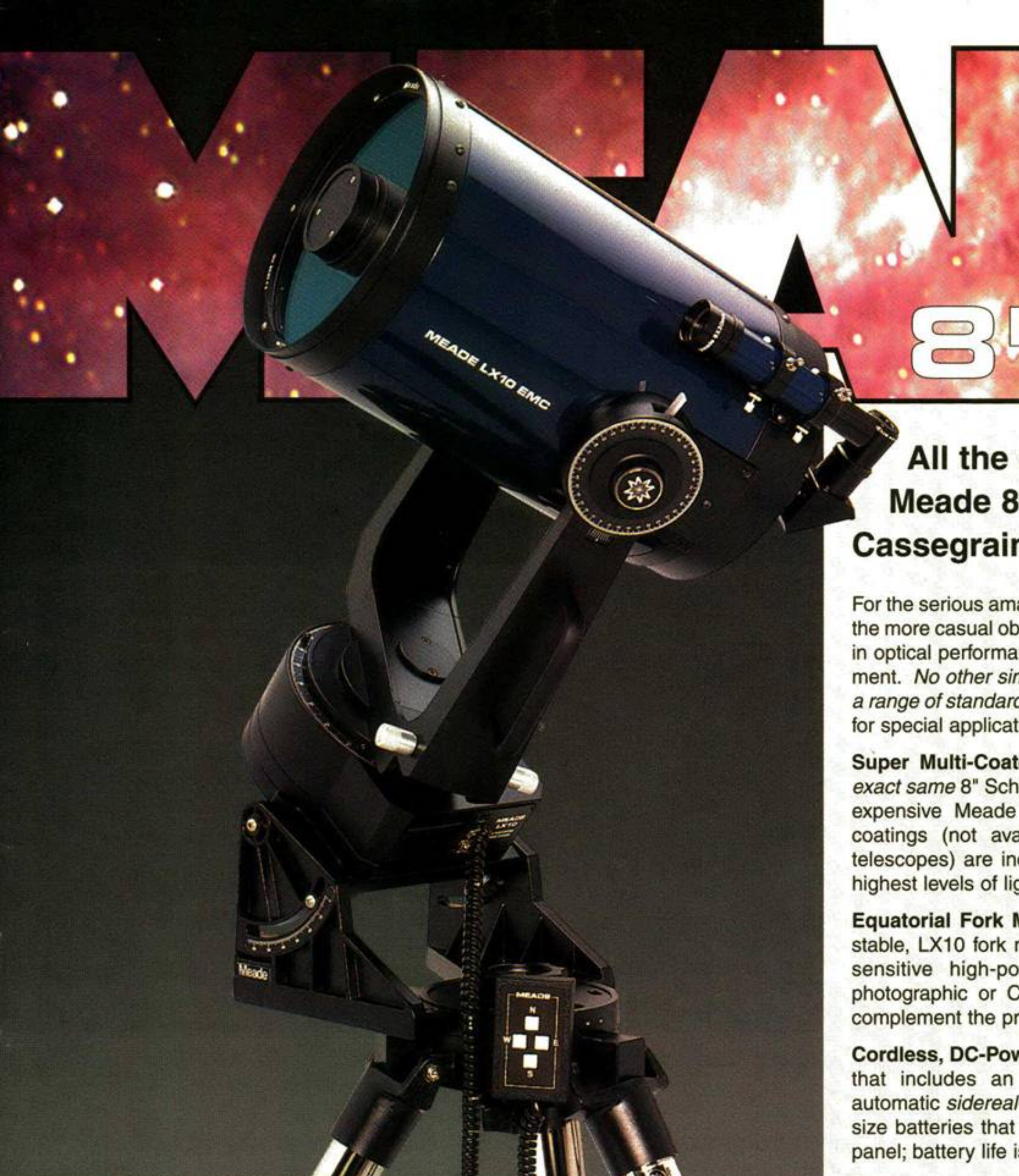


MEADE 8" LX10

All the optical performance of Meade 8" LX50 and LX200 Schmidt Cassegrains...for only *$995!*

For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *No other similarly-priced 8" Schmidt-Cassegrain offers such a range of standard features* — or such a range of important options for special applications. *Standard-equipment includes:*

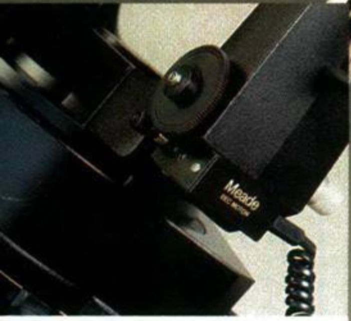
Super Multi-Coated Optical System: The LX10 includes the *exact same* 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. Super multi-coatings (not available even as an *option* on competing 8" telescopes) are included with every LX10 optical system, for the highest levels of light transmission and image contrast.

Equatorial Fork Mounting: The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. Ball bearings on the polar axis complement the precise action of the internal worm gear system.

Cordless, DC-Powered Electronic Motor Drive: A drive system that includes an electronically-regulated DC servo motor for automatic *sidereal-rate* tracking. The drive is powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours.

Worm-Gear System: The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

Hand Controller: Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.



Add the optional LX10 Declination Motor for dual-axis corrections at 2x.

Meade 8" LX10
Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions.
$995. (+ $65 packing & shipping in the 48 states)

LX10 Field Tripod	**195.**
LX10 Electric Declination Motor System	**85.**
#2014 Magellan I Telescope Computer System for LX10, with 12,218-object database	**375.**

The 94-page Meade 1996 General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers. Prices shown are suggested U.S. mail-order prices.

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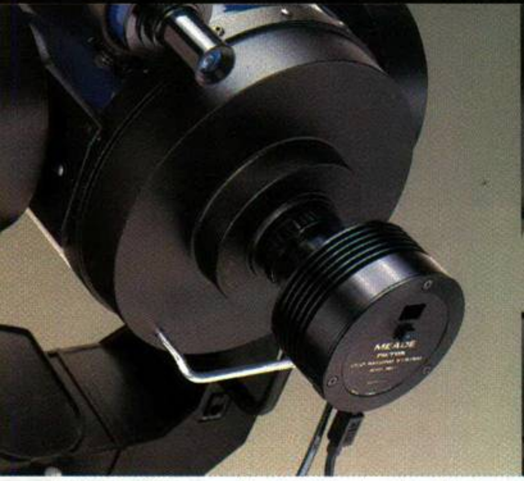
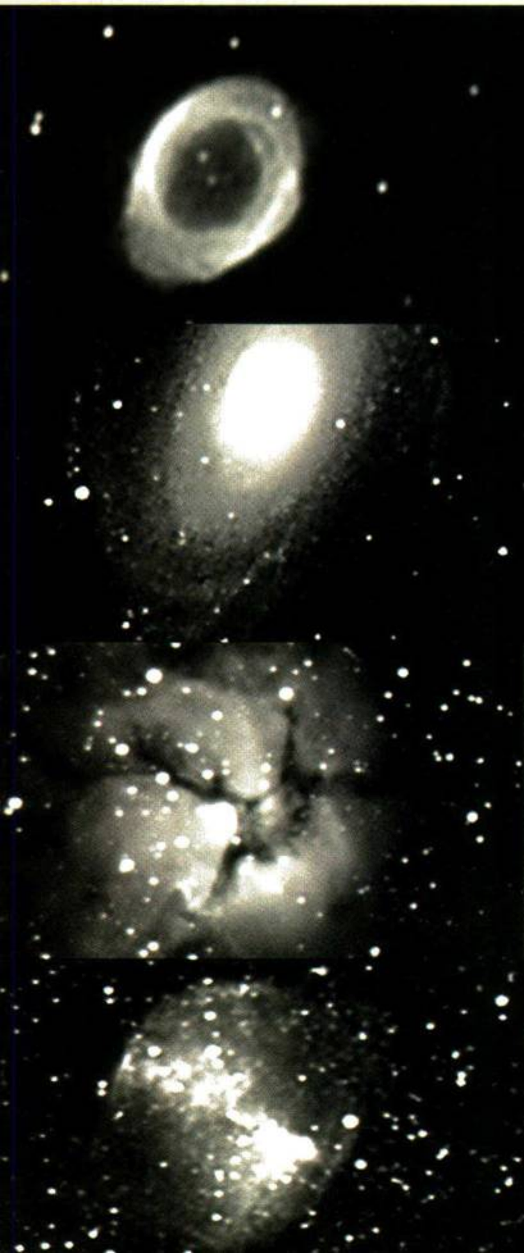
Meade Pictor 208XT

AUTOGUIDER/IMAGER

complete **$495**



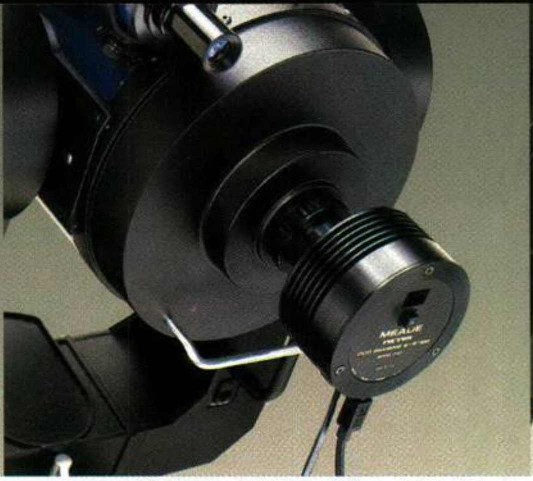
Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot; Dumbbell Nebula (M27), 12" LX200, John Hoot.



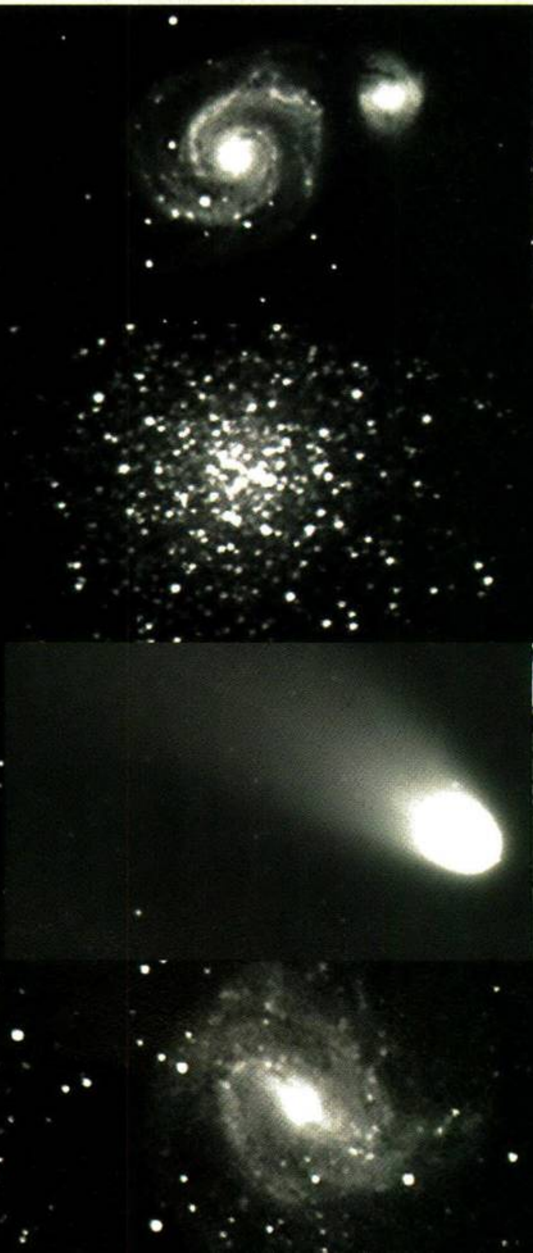
Meade Pictor 216XT

AUTOGUIDER/IMAGER

complete **$695**



Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Comet Hyakutake, 8" LX200 with f/6.3 Focal Reducer, John Hoot; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.

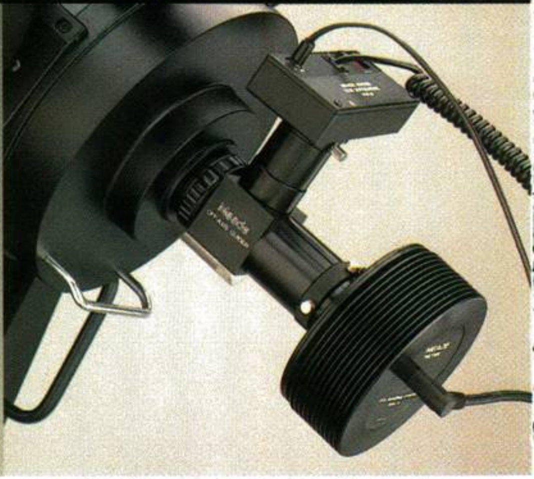


Meade Pictor 416XT

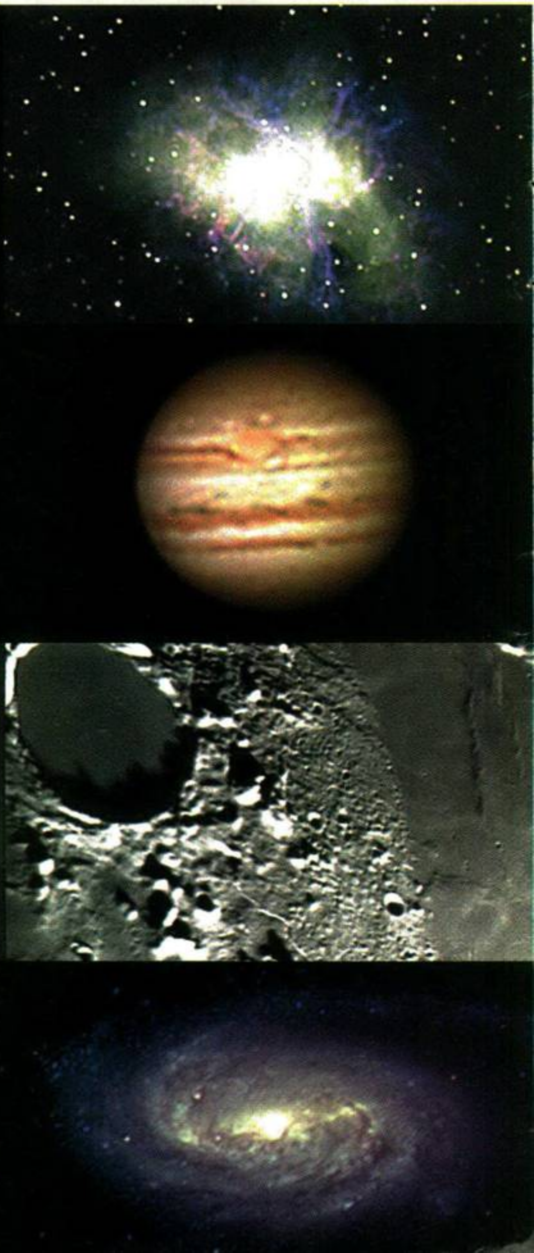
AUTOGUIDER/IMAGER

complete **$1695**

includes $800 Meade CCD Equipment System



Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker; NGC 2903, 25" reflector, Jack Newton.



MEADE

XT-SERIES CCD IMAGERS

Now you can buy a high-performance Meade® CCD imager for as little as *$495!*

Meade Instruments has just made high-performance CCD imaging affordable for everyone. New Meade Pictor XT-Series imagers offer more features, more high-resolution imaging, and more easy-to-follow menu options than any imagers ever made available. *You can pay $500 to $1000 more for competing CCD units and still not obtain the advanced capabilities of Meade XT-series imagers.* Choose the Meade imager that is right for your budget and applications. *All models are supplied complete and ready-to-use and are available for immediate delivery:*

Pictor 208XT Autoguider/Imager

One of the most revolutionary astronomical products ever developed, the Meade Pictor 208XT has opened up the field of CCD imaging potentially to tens of thousands of serious amateurs worldwide. In the 208XT astronomers have at last a truly remarkable, high-performance imager at an amazingly low price. One look at the Pictor 208XT will convince its owner that he or she has purchased a product of exquisite quality, an almost magical electronic instrument that produces on the PC display, in 2 or 3 minutes, fine, high-resolution images of thousands of deep-space objects or, in seconds, of the Moon and planets.

Specifications: Includes autoguider/imager body (4" dia.) with digital readout of operating data and with Texas Instruments TC-255 CCD chip (3.30 x 2.40mm; 336 x 242 pixels; pixel size: 10µm - square); 8-bit A/D conversion for 256 gray-levels in the image; 1.25" barrel for standard eyepiece-holders; cords for connection to telescope and PC. Software features: image transfer and display; contrast control; smoothing/sharpening filters; automatic and manual exposure levels; automatic dark-field exposure and flat-field sequence; pixel binning. Operating manual. **$495.** (+ $20 packing and shipping in 48 states)

Pictor 216XT Autoguider/Imager

By far the finest autoguider/imager ever made available in its price class, the 216XT enables advanced imaging applications. Identical in operating characteristics to the 208XT, the Pictor 216XT includes two additional important features at moderate additional cost: (a) A 16-bit analog-to-digital converter (compared to the 208XT's 8-bit converter), permitting 65,536 gray levels for smoother, more natural images; (b) External connectors and onboard software that allow the 216XT to be used with the Pictor 616 Color Filter System for tri-color imaging. *The Pictor 216XT is the only imager available with these capabilities within $500 of the 216XT's price. The 216XT is all the imager ever required by the majority of amateur astronomers.*

Specifications—Includes autoguider/imager body (4" dia.) with digital readout of operating data and with Texas Instruments TC-255 CCD chip (3.30 x 2.40mm; 336 x 242 pixels; pixel size: 10µm - square); 16-bit A/D conversion for 65,536 gray-levels; 1.25" barrel for standard eyepiece-holders; cords for connection to telescope and PC. Software features: same as for Pictor 208XT *(above),* and with software provision for attachment to Pictor 616 Color Filter System. Operating manual. **$695.** (+$25 P & S)

Pictor 416XT Autoguider/Imager

The amateur astronomer's dream of professional-level imaging capability, the Meade Pictor 416XT is armed with the powerful Kodak KAF-0400 CCD microchip and the latest in Meade operating software. The most advanced CCD system available at under-$5000, and yet one of the easiest to use, the 416XT is capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes.

For a limited time the Pictor 416XT includes **at no additional charge** the $800 Meade CCD Equipment System *(see photo),* with the **Meade Pictor 201XT CCD Autoguider** ($395); **Meade CCD Off-Axis Guider System,** with 1.25" and Schmidt-Cassegrain attachment barrels ($119); **Meade CCD Image-Orientation Adapter** ($35); **Meade Epoch 2000ip Image Processing Software** ($199); **Meade Deluxe Carrying Case** ($59).

Specifications—Includes autoguider/imager body (5" dia.) and control box with digital readout display and keypad; incorporates Kodak KAF-0400 CCD chip (6.90 x 4.60mm; 768 x 512 pixels; pixel size: 9µm - square); 16-bit A/D conversion for 65,536 gray-levels in the image; CCD Equipment System, described above; SCSI interface for one-second downloading; 1.25" barrel for standard eyepiece-holders; cords for connection to telescope and PC. Software features: same as for Pictor 208XT *(left),* and with software provision for attachment to Pictor 616 Color Filter System. Operating manual. **$1695.** (+$40 P & S)

Pictor 416XT imagers are shipped at no additional charge with the $800 Meade CCD Equipment System.

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ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
16542 Millikan Avenue, Irvine, Calif. 92606
(714) 756-2291 □ FAX: (714) 756-1450

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MEADE STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of *standard-equipment* features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package
only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

3 - **Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I
Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

MEADE
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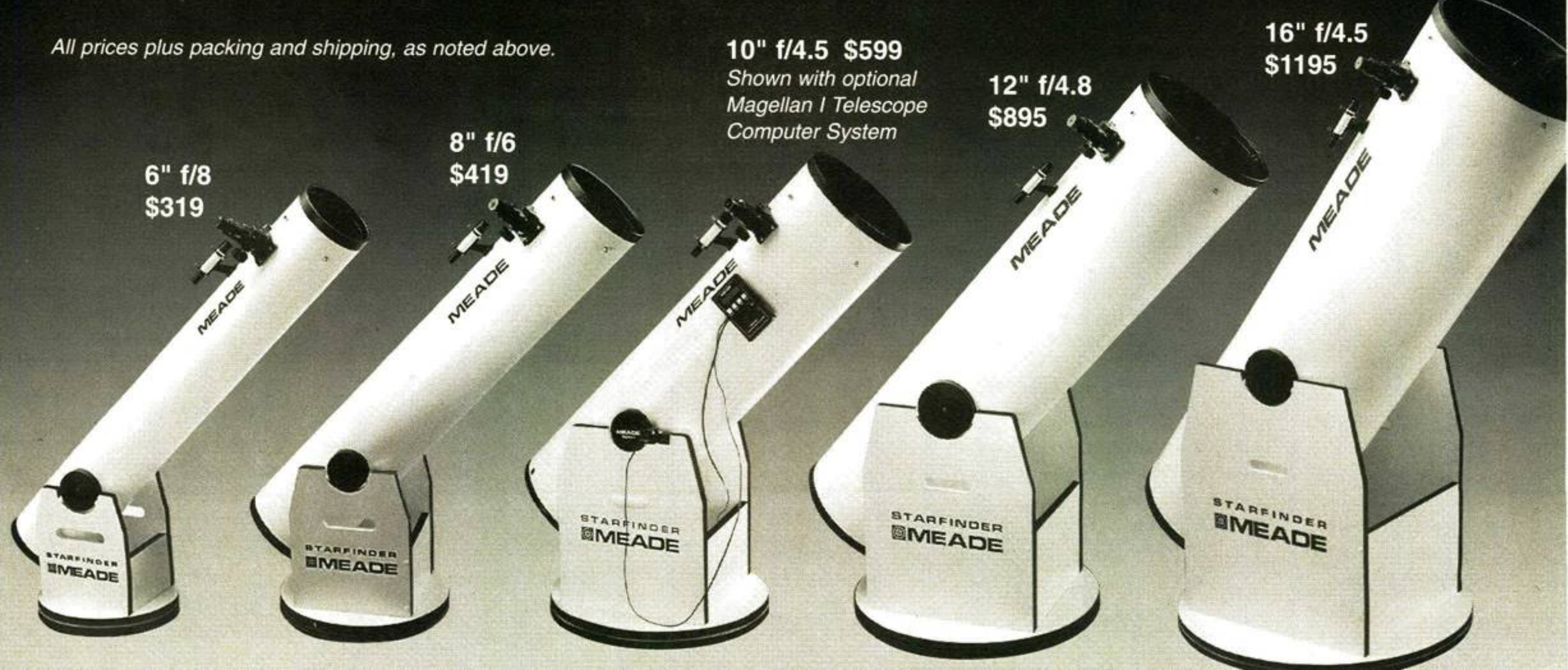
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***



All prices plus packing and shipping, as noted above.

6" f/8
$319

8" f/6
$419

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12" f/4.8
$895

16" f/4.5
$1195

MEADE STARFINDER EQUATORIALS

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

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MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page)*.

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

MEADE
MAGELLAN II
COMPUTER-CORRECTOR
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Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*

The fullest exposition of Meade astronomical telescopes, CCD imagers, and telescope accessories is contained in the 94-page Meade 1997 General Catalog.

Write, call, or fax Meade Instruments for your free copy!

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SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Illinois & Info.: 312-332-2000.

Canada:

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Orders & Information: 416-787-4581.

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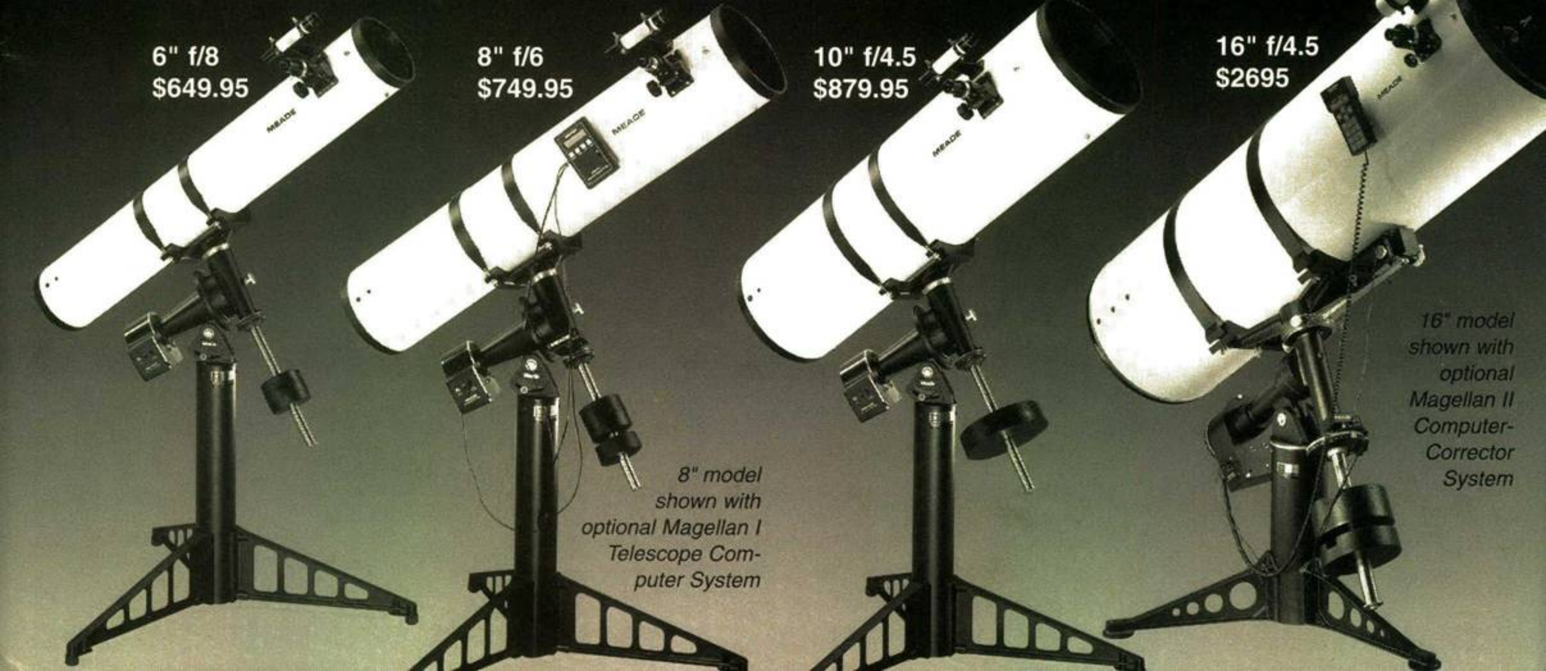
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



6" f/8
$649.95

8" f/6
$749.95

10" f/4.5
$879.95

16" f/4.5
$2695

8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

MEADE
MEADE 127ED/APO EMC
Meade LXD 650 U.S.A.

Meade Model 127ED:
5" *ED* Apochromatic Refractor.
Shown with optional #1697
Computer Drive System.

***Background image:* the Omega Nebula (M17) —**
A 5-minute image by Jack Newton using the
Meade 7" *ED* Apochromatic Refractor and Meade
Pictor 1616 CCD Imager.

ED APOCHROMATIC REFRACTORS

"This is the best black-and-white CCD image of M17 that I have ever taken with any telescope. I just couldn't believe that this could be done in a 5-minute shot with a CCD camera and a 7" refractor. I'm amazed at how the telescope performs, even against my own 25" Newtonian." **—Jack Newton**

Fortunate indeed is the observer with a Meade *ED* Apochromatic Refractor at his or her disposal, for these are professional-class instruments capable of serious research. Observe structural detail and color variations within Jupiter's Red Spot and at the boundaries of 8 to 10 cloud belts; resolve all three of Saturn's main rings and substructures within the rings themselves. *Simply put, if you're looking for the finest, textbook-perfect, ultra-high-resolution, high-contrast imaging of the skies that astronomical instrumentation, of any type, can provide, then a Meade ED Apochromatic Refractor is for you.*

Use the massive Meade **LXD 650** (4", 5") or **LXD 750** (6", 7") equatorial mounts in conjunction with the optional **#1697 Computer Drive System** to slew the telescope across the sky and computer-point the instrument, automatically, *to a precision of one arc-minute.* ***Meade LXD mounts are the only commercially-available German-type mounts capable of such a feat.*** Actuate any of 9 pushbutton-controlled drive speeds (from 2x photoguide to 8°/sec. fast-slew) on both axes, automatically, to locate and center any object directly from its input R.A. and Dec. Or use the onboard database for even faster object centering. Included with the #1697 CDS, the Meade **Smart Drive**™ assures the extremely low periodic error essential to research-level photographic or CCD imaging.

More than 40 Meade optional accessories are available to suit virtually any observing, photographic, or CCD imaging requirement.

Supplied complete per catalog specifications:

4" f/9 Model 102ED	**$2795.**
5" f/9 Model 127ED	**3295.**
6" f/9 Model 152ED	**4995.**
7" f/9 Model 178ED	**5995.**
#1697 Computer Drive System	**695.**

Packing and shipping in the 48 states: 4"—$105; 5"—$125; 6"—$185; 7"—$215.

MEADE
EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD F

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

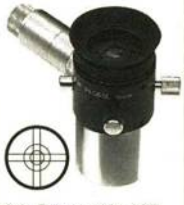
#929 or **#930,** each: **$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#905 Variable Polarizer (1.25")

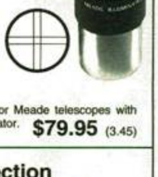
For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 3000™ Plössls 50° field; multi-coated

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

HOW TO ORDER

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KHAN SCOPE CENTRE, Toronto, Ontario.
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ODYSSEY™
TELESCOPES
Seeing the *real* Universe

PRESS RELEASE:
MURNAGHAN Instruments Buys Coulter Optical Assets. Production of **Odyssey™ Telescopes** will continue. New product benefits from financial stability and management of MURNAGHAN Instruments Corporation.

THE ODYSSEY™ ADVANTAGE
- No assembly required
- Improved Dob mount and Focuser
- Double-strength Sonotube
- Eyepiece included
- Many options available
- Lowest prices anywhere

8-INCH f/4.5 $399.95
- Deep-space scope
- Tube 36 × 9.5 inches
- Diffraction-limited optics
- Includes wide-field eyepiece
- Reengineered mount system

8-INCH f/7 $399.95
- Lunar/planetary scope
- Tube 57 × 9.5 inches
- Diffraction-limited optics
- Includes high-magnification eyepiece
- Extra-stable mount

10-INCH f/4.5 $499.95
- Extremely portable
- Tube 44 × 12.7 inches
- Diffraction-limited optics
- Includes wide-field eyepiece
- Improved mount system

13.1-INCH f/4.5 $799.95
- A BIG scope for less money
- Easy 1-person setup
- Tube 57 × 15.7 inches
- Diffraction-limited optics
- Includes wide-field eyepiece

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ASTRO LETTERS

Funding for the Future?

The recent news has focused on suspected microfossils found in the Mars meteorite. The media jumped on the bandwagon in a heartbeat.

All along scientists have theorized that microbes may have formed in the past when Mars had a thicker atmosphere. Next, ABC News reported that Europa's cracked, icy surface may have been created by water flowing beneath it, and suggested that life could exist or once existed. Suddenly our solar system is blooming with life. The media should be told about Saturn's moon, Titan, which possesses a thick atmosphere. Titan, too, is suspected of conditions favorable for life in the past.

It's a shame that financial support has to wait until the media makes a headline out of a discovery. — *Keith Limper, Philadelphia, Pennsylvania*

Next Stop — Mars and Venus?

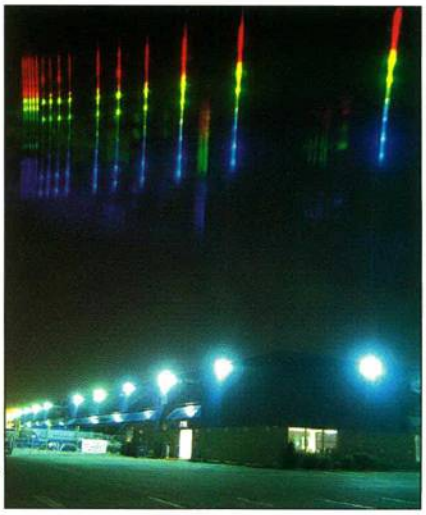
There is a lot of interest among Internet astronomy news groups about terraforming Mars and Venus. Humans already have 200 years of experience terraforming Earth.

With the emissions of the industrial age accumulating for more than two centuries, we may have already diminished the glaciers, begun the retreat of the polar ice caps, blanketed our mega-cities in noxious vapors, and ripped holes in the ozone.

Perhaps that meteorite from Mars bearing possible fossilized life was sent to deliver the message, "No thanks!" — *Robert James Jackson, Muskegon, Michigan, Tristan66@aol.com*

City Lights Are Too Bright

"How to Beat Light Pollution" (September 1995) appropriately addressed the issue of who or what to target when discussing lighting problems and solutions in communities that are considering changes in lighting. Apparently, when mercury vapor lights fail, many communities replace them with "multi-vapor" lights or high-pressure sodium lights.


George Liv

Flooding the night with light, multi-vapor lamps are used exclusively in this new building.

This type of light was once common in bright lots and ball-parks. The spectrum of multi-vapors exhibits many emission lines, while mercury vapor has only four. The result on the night sky is appalling. When snow is on the ground, little can be seen in the best of conditions. Only 5th-magnitude stars are visible an hour's drive from Montréal.

I am concerned these lights will spread unchecked as did high-pressure sodium lights. If amateur astronomers don't put a stop to this, no one will. Lighting companies and manufacturers stand to profit further at the immense cost of dark skies. — *George Liv, St. Laurent, Québec*

Awesome Hubble Bash

As I read through "Hubble's Birthday Bash" (August 1996) I realized how beneficial the Hubble Space Telescope really is. I have a 4-inch telescope and when I see these awesome pictures taken above Earth's atmosphere I appreciate what Hubble has done for the world.

The scientists who use it are receiving unparalleled data about our universe. We can only imagine how much more there is to learn. — *Paul M. Schwartz, Gettysburg, Pennsylvania*

Light-Tight Scope

The simple suggestions in "Make Your Scope Light-Tight" (September 1996) made a tremendous difference in my telescope's performance. Even though my observing site is my backyard in the suburbs, I'm now resolving more cloud bands on Jupiter and star clusters that were previously unknown to me. — *Paul Coker, Aurora, Colorado*

PortaScope Re-visited

I recently built the PortaScope from plans you published in the two-part article, "Build a 10-Inch PortaScope" (January and February, 1995). My children and I enjoyed this project and are proud of the results. Due to the size of my mirror, an 8-inch f/6.25, I had to modify the plans, and because it already had a mirror cell, I didn't build one. I made my removable mirror panel less than the length of that tube section because my mirror-end of the tube was much longer than the one in the article. Additionally, I used Teflon instead of nylon in both the azimuth and altitude bearings.

Thanks to ASTRONOMY and David Bruning for this excellent article which allowed me to build a decent telescope. — *Richard Mueller, Red Deer, Alberta*

Terzans Are Tough Customers

I had just finished observing the Terzan globular star clusters when I read "Faint Balls of Fire" (September 1996); congratulations on the fine article. I know how difficult these globulars can be. While working with POSS plates I noticed some possible discrepancies with Terzan 9 and 11 — the Terzan globulars appear only on the red plates, while the blue plates show nothing, as would be expected from these objects obscured by interstellar dust.

But when I looked at Terzan 9, the red plate (and my 13-inch telescope) showed nothing obvious at the location given by the POSS plate's transparent overlay. There was, however, a condensed, familiar-looking, yet unidentified spot about 4' northwest.

The same thing was true for Terzan 11. While there's a very small, slightly fuzzy spot at the overlay's location, there is also a prominent condensation about 5' to the west. When I checked visually, my tele-

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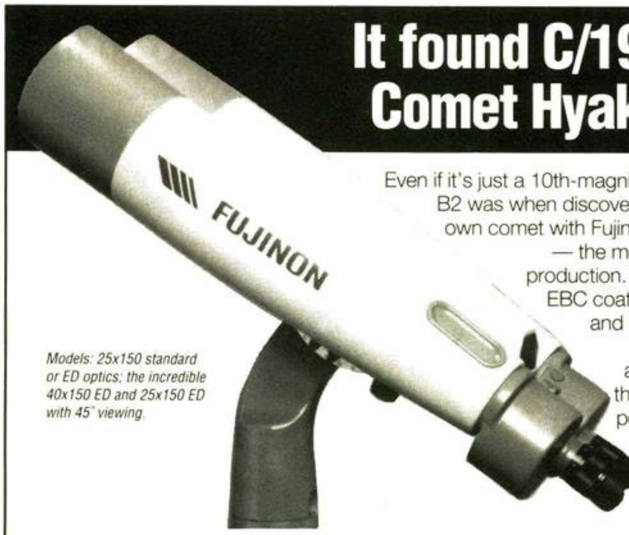

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scope showed neither. Which object is the real Terzan 11? — *Tom Johnston, Boulder, Colorado, viewsn@juno.com*

Richard Mueller

Richard Mueller and his children built this 8-inch PortaScope from plans published in ASTRONOMY.

Jupiter Eclipse Web Site

Many ASTRONOMY readers enjoy watching eclipses of the Galilean satellites, and now there is a web site devoted to those observations located at http://members.aol.com/galilean/intro.htm — *Anthony Mallama, tmallama@smtp2.stx.com*

E-Ring Update

The E Ring was discovered photographically on a series of 50 photographs, ("The Lost Ring of Saturn," September 1996), and its faintness rules out visual sightings. Authors Baum and Dobbins do not mention the CCD confirmations from several ground-based observatories during the 1980 edge-on presentation of the ring plane. Nor do they mention the widely accepted view that it is replenished by particles from Saturn's moon Enceladus. — *Walter A. Feibelman, Goddard Space Flight Center, Greenbelt, Maryland*

Small Scopes Not Forgotten

Thank you for creating the Small Scope Showcase ("Discover the Autumn Sky," September 1996).

Finally, I do not feel as if I am the only person reading ASTRONOMY who owns one of those ubiquitous "department-store" telescopes. Someday I hope to have the funds to upgrade to a larger scope, but until then, I'm pleased that ASTRONOMY has not forgotten true those of us attempting to discern the secrets of the universe through tiny telescopes. — *S. D. Tortorice, Long Island, New York*

NASA Projects for K-12

Two projects that were announced in April 1996 are now in their startup phases. Both projects will connect students in grades K-12 with the men and women involved in modern space research. — *Marc Siegel, NASA K-12 IITA Program, marc@quest.arc.nasa.gov*

Project S/MORE: Runs from October–December 1996 and focuses on the life science/biology research being conducted onboard the Shuttle/MIR by active astronauts.

Plant research will be highlighted, but some experiments with humans and animals will also be covered.

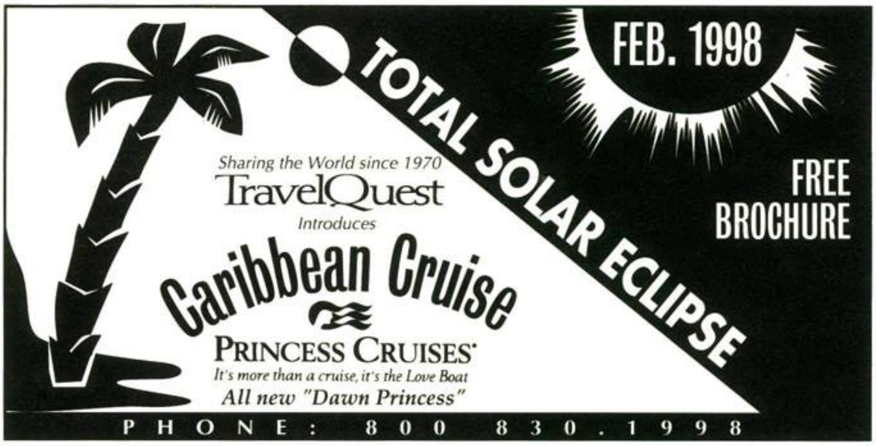
S/MORE's website may be found at http://quest.arc.nasa.gov/smore .

Live From Mars: Runs throughout the entire 1996–1997 school year. In late 1996, NASA will initiate a new era of Mars exploration with the launch of two missions to Mars. One project will land on the surface and deploy a roving vehicle for a 30-day exploration; the other mission will orbit Mars to map the planet and study its weather. In addition to a mission focus, "Live From Mars" will explore the science behind the missions, including what we hope to learn from Mars and how it relates to life on Earth.

The Live From Mars website may be found at http://quest.arc.nasa.gov/mars.

For further information regarding the programs, please email marc@quest.arc.nasa.gov. ☐

ASTRONOMY welcomes feedback. Send it to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187, or on the Internet use letters@astronomy. com. Letters may be edited for space and clarity.



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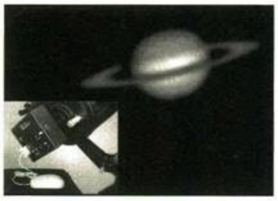
Saturn, 8-inch with Barlow lens. Inset: CWIP-S shown with mouse. No computer is required.



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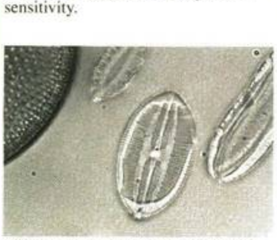

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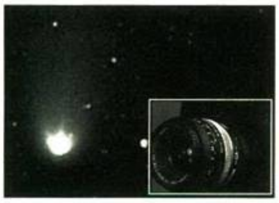

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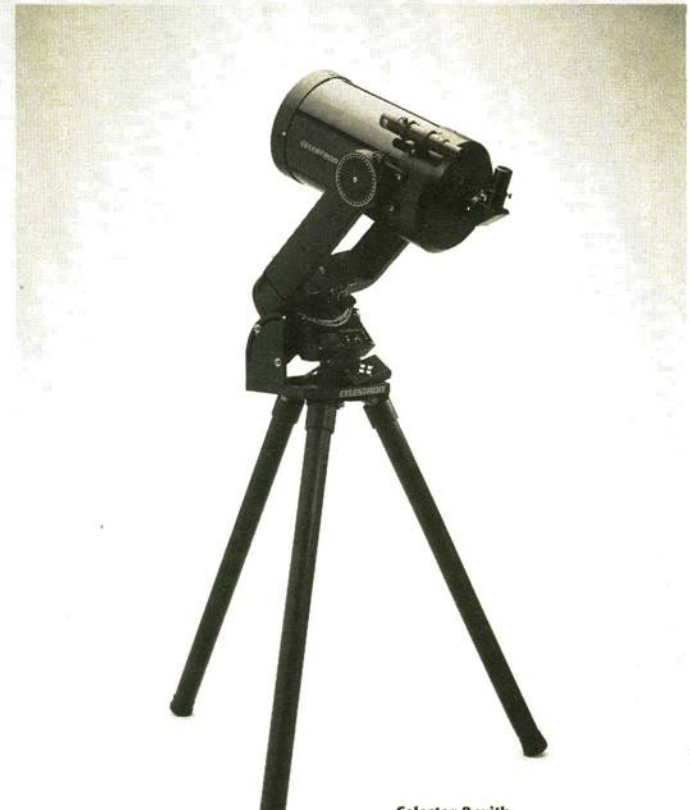

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M27. *Tricolor CCD image taken with a Celestron C-8 at f/6.3 with an ST-7 CCD imaging camera and CFW-8 Color Filter wheel. Courtesy Benoit Schillings, Los Altos, California.*

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Moon over Marathon

The Moon played a critical role in one of Athens' most heroic moments — and later, in one of her greatest disasters.

by William Sheehan and Michael Armstrong

The mountains look on Marathon –
And Marathon looks on the sea;
And musing there an hour alone,
I dreamed that Greece might still be free.
— Lord Byron

The battle of Marathon was one of the turning points in Greek, and hence in all western history. The men who fought at Marathon in September 490 B.C. would remember it as the high point of their lives. Even today we still recall the mythological feat of the Athenian runner Pheidippides who, after running the 40 kilometers to Athens after the battle, was said to have gasped "rejoice, we conquer," and fell dead of exhaustion.

The details are recounted by the Greek historian Herodotus. Oddly enough, the Moon played a pivotal role in these great events.

The Persians, under King Darius I, crossed the Aegean Sea intending to subjugate the Greeks. The Persians landed on the bay of Marathon near Athens, and in alarm the Athenian Assembly resolved to meet their formidable foes there, rather than await their arrival in Athens. Meanwhile they sent Pheidippides to Sparta, Greece's chief military power, to request aid.

Pheidippides covered the 225 kilometers in only two days. At the time the Spartans were celebrating the festival of Apollo Karneios, and though they were willing to help Athens, their laws forbade them from undertaking any military operation until after the full Moon had passed, six days later. Pheidippides returned to Athens alone.

H. S. E. Newton

While the Spartans waited for the full Moon, the Athenians fought their way to glory at Marathon.

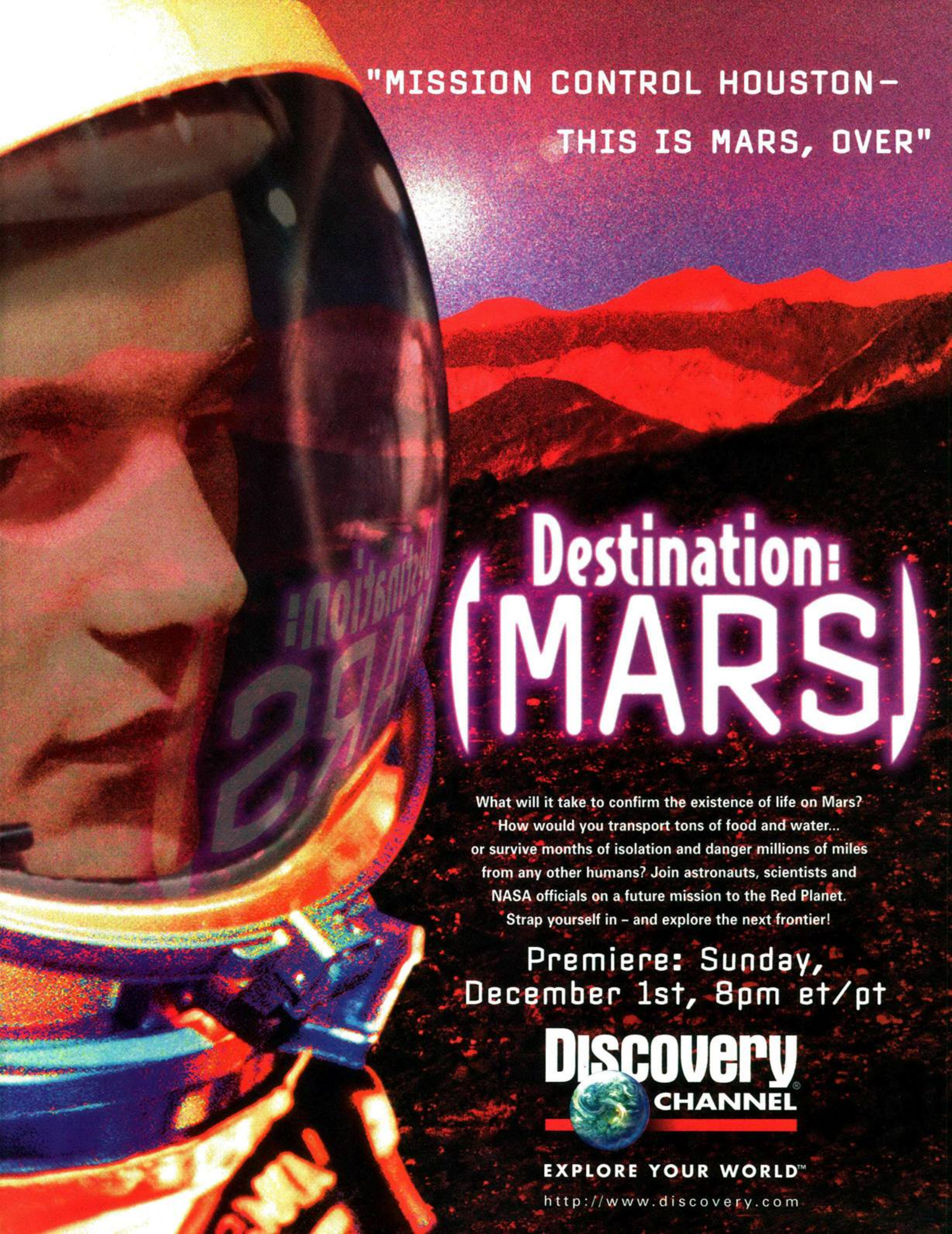
The date of the full Moon was September 9, 490 B.C. On the following morning the Spartans did indeed set out. According to Herodotus, "They were so eager to arrive in time that they took but three days to reach Attica from Sparta." Even so they came too late and found that the great battle was over. The Athenians, with the help of the small allied city Plataea, had beaten back the numerically vastly superior Persians.

Athens won tremendous prestige and self-confidence by defeating the "barbarians" virtually single-handedly. Oligarchic, repressive Sparta had always been the acknowledged leader of the Greek city-states, but Sparta had no share in the victory at Marathon. Democratic Athens was now to become, in her own eyes and in the eyes of many other Greeks, the preeminent champion against the Persians. The victory at Marathon launched Athens on a near-century of prosperity, broadening democratic government, and unparalleled cultural development — and of imperialistic arrogance and domination as well. This was the so-called "Golden Age of Athens." Sparta's religious scruples about the phase of the Moon indirectly paved the way for Athens' rise to prominence.

If the Moon contributed to Athens' dramatic success at Marathon and her future greatness, ironically it also played a role in one of her most tragic defeats.

During the Peloponnesian wars between former allies Athens and Sparta, one of the turning points involved the Athenian expedition to Sparta's ally Syracuse in 415–413 B.C. The story of Athens' imperial overreaching is told with brilliance and pathos by Greek historian Thucydides, and is the climax of his great history. The Athenian fleet anchored itself in the Great Harbor of Syracuse, and began to build siege works around the city. For a time it seemed that success was imminent, but eventually the Syracusans rallied, and won a great battle over the Athenian fleet.

The Athenians still controlled the harbor and its entrance, and they



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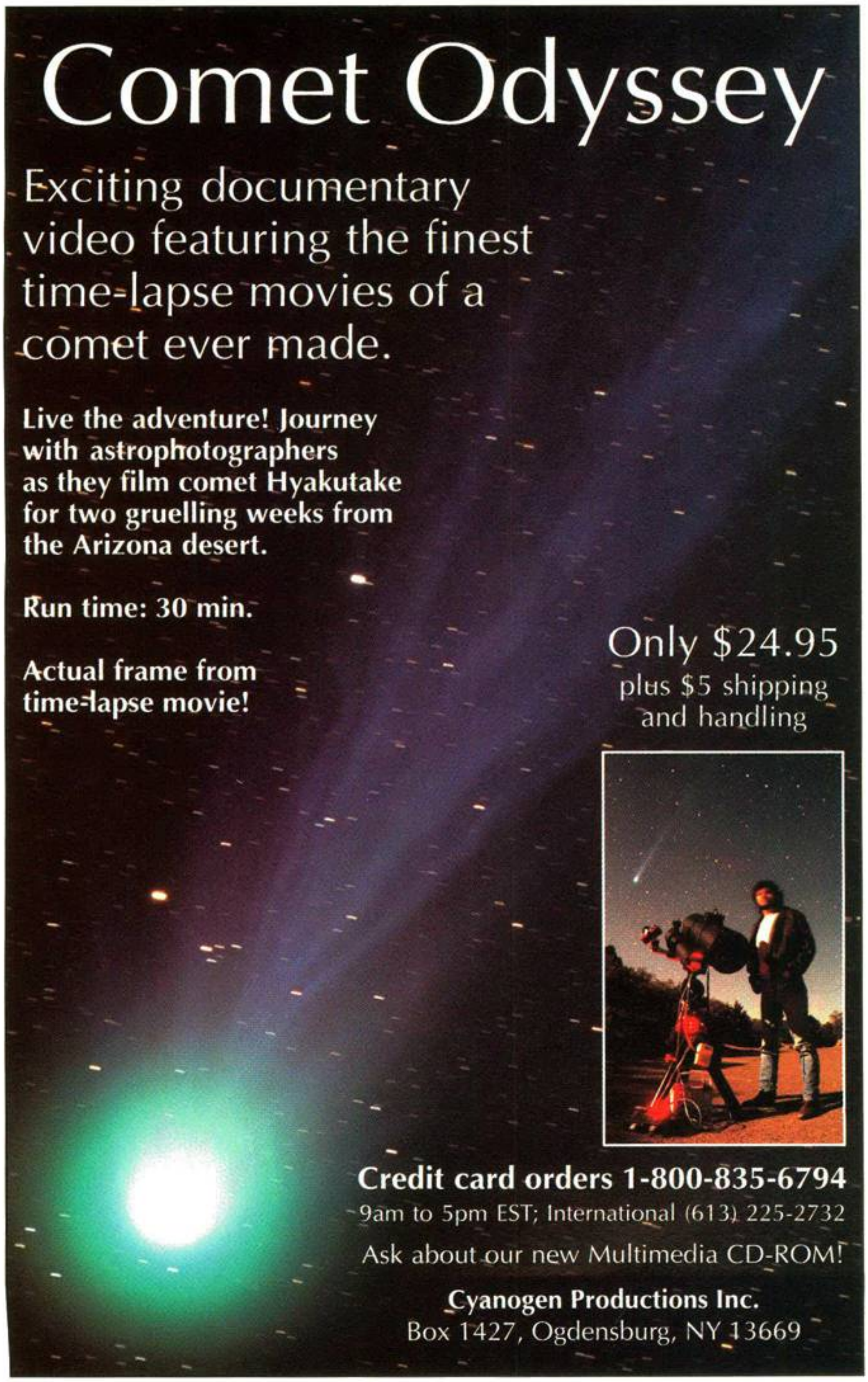

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could have evacuated their positions and saved their army if they had acted at once. But on the eve of when they were to set sail, August 27, 413 B.C., an eclipse of the Moon occurred. The chief Athenian commander Nicias accepted the decision of the soothsayers and resolved to wait "thrice nine days" until the next full Moon before sailing.

The delay was disastrous. "Abandoning almost everything else," the biographer Plutarch writes, "Nicias sat there sacrificing and divining until the enemy came up against him." By the time the 27 days had passed, the Athenians' escape route had been blockaded by the Syracusans, and after a ferocious battle in the harbor, the Athenians realized they were trapped.

The Athenian generals Nicias and Demosthenes attempted to fight their way out by land. But they lost contact with each other, were pursued by the Syracusans, and were separately defeated. Nicias and Demosthenes were put to death, and some 7,000 Athenian prisoners were thrown into stone quarries, where most of them died slowly of thirst and exposure amongst the rotting corpses of their dead comrades. Of the Athenian debacle at Syracuse, Thucydides notes: "The event proved to be the greatest of all that happened in this war." Athens' allies abandoned her when they heard of the calamitous defeat. Athens fought on against Sparta for 10 more years, with some brilliant successes, but the defeat at Syracuse foreshadowed her ultimate downfall.

So the Moon once again played its role in the tides of human affairs. At the battle of Marathon, it had shone brightly on one of Athens' most glorious triumphs; while at Syracuse it cast its gloom over one of her most disastrous defeats. Oh the inconstant Moon! □

William Sheehan co-authored the story of Neptune's discovery in the September 1996 issue. Michael Armstrong is a professor of classics at Hobart and William Smith Colleges in Geneva, New York.

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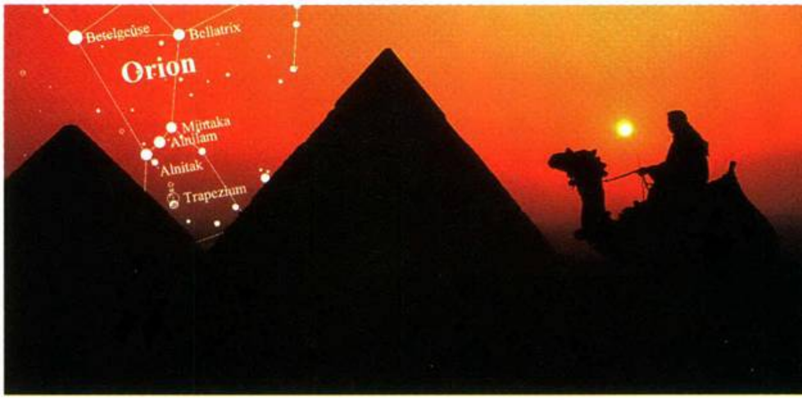

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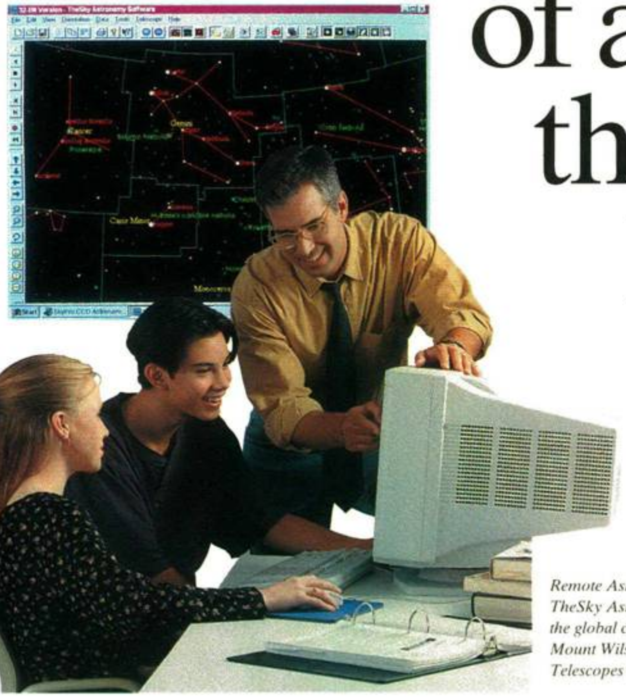

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Come Together

Astronomers have glimpsed distant galaxies that existed one billion years after the Big Bang, but they have long wished to see the smaller structures from which galaxies formed. This hope may have become reality.

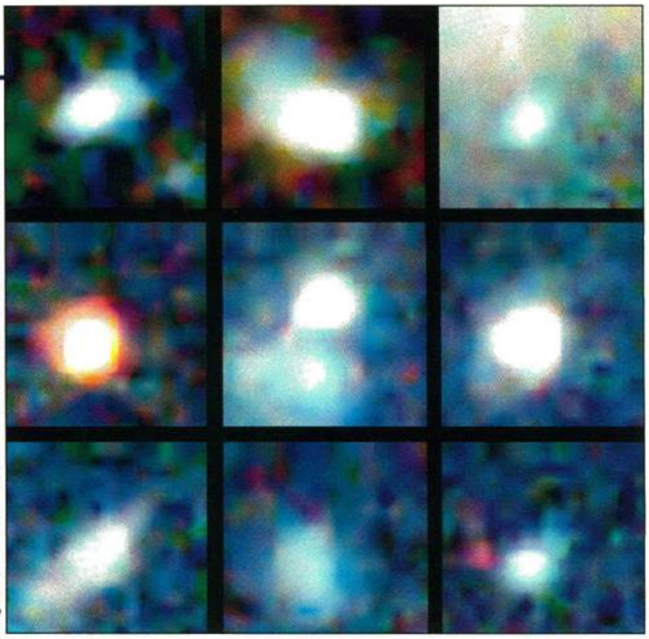
A new Hubble Space Telescope two-day exposure reveals 18 clumps containing several billion stars each. Based on the velocity of these clumps and the fact they are crammed into an area only 2 million light-years across, a team of astronomers led by Sebastian Pascarelle of Arizona State University concludes they will eventually merge into a single, galaxy-size object.

These clumps are about 11 billion light-years away, meaning they existed when the universe was 16 percent of its current age. The clumps are only 2,000 to 3,000 light-years across, much smaller than the 100,000 light-year-wide Milky Way Galaxy. They are even smaller than the Milky Way's central bulge, which is 8,000 light-years across. "We think that by repeated merging, the clumps will grow big enough to become the bulges of galaxies," says team-member William Keel of the University of Alabama.

The Hubble image supports the theory that galaxies formed from small building blocks that merged, rather than from gigantic gas clouds that collapsed under the force of gravity. In this picture, the older stars in the Milky Way's bulge formed from mergers of sub-galactic units. The bulge later gravitationally captured surrounding gas clouds, which formed the younger stars that populate the galactic disk.

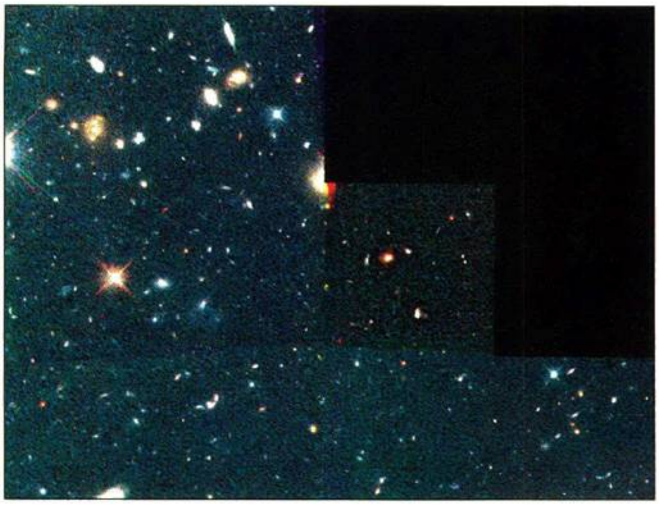
University of Washington astronomer Bruce Margon cautions, "All we can say is that we are almost surely seeing several small structures that are going to assemble into a larger structure. Whether this is the standard way that all galaxies are made is a question that will be stimulated by this work."

Ground-based telescopes don't have the resolution to see such tiny structures at such great distances. "It's always been a joke of nature that we knew that there had to be some distance back toward the Big Bang where galaxies began to form, but it always seemed to be just barely beyond the grasp of the best telescopes," says Margon. "This is the first page of an otherwise blank book."



Rogier Windhorst and Sam Pascarelle (Arizona State Univ.) and NASA

A few billion young, blue stars are packed into each of these 9 clusters, which are about 2,000 light-years across. Two clusters appear double, as if they are being caught in the act of merging. The smallest clumps are only 1/10 of an arcsecond wide.



Rogier Windhorst and Sam Pascarelle (Arizona State Univ.) and NASA

Inside this Hubble image are 18 star clusters that could be galactic building blocks. Located about 11 billion light-years away, they are crammed into a region only 2 million light-years across — shorter than the distance between the Milky Way and Andromeda galaxies. Astronomers think they will merge to form a galaxy.

Collisions in the Kuiper Belt

The solar system's frigid outer realm might be a more violent and dynamic place than astronomers had imagined. Two recent findings point to frequent collisions among the small, icy worlds in the Kuiper Belt, the reservoir of comets that starts just beyond the orbit of Neptune.

First, Jane Luu of Harvard University and David Jewitt of the University of Hawaii measured the colors of 14 Kuiper Belt objects, along with four of the six known Centaurs, objects that orbit in the realm of the giant planets but that are thought to have originated in the Kuiper Belt. Luu and Jewitt expected these icy bodies to have a uniform red color, the result of exposure to cosmic rays over billions of years.

Instead, they found that the objects exhibited many different colors. Luu and Jewitt suspect that these objects are being resurfaced by collisions. "We *used to think* that the Kuiper Belt was a place where nothing ever happened, but in fact there's a

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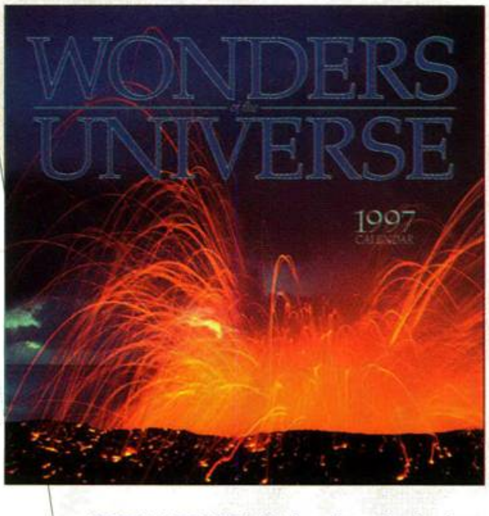

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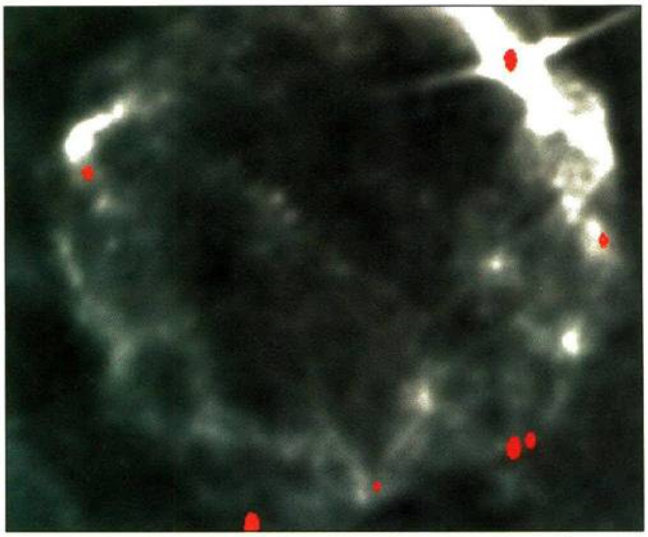
lot going on there," says Jewitt.

Second, computer simulations by Paolo Farinella of the University of Pisa in Italy and Donald Davis of the Planetary Science Institute in Arizona indicate that the smaller bodies in the Kuiper Belt frequently collide with one another. These collisions may ultimately kick short-period comets into the inner solar system. If true, this means that short-period comets are not the pristine objects that astronomers had once thought. Astronomers now think that at least a billion kilometer-sized comet nuclei roam the dark regions beyond Neptune.

Shocking Conditions Excite Masers

Stellar death and birth may be occurring simultaneously in this radio image (top center) of a 160-light-year-wide shell-type supernova remnant that is slamming into a dense molecular cloud (from which stars are born). Located not far from the galactic center, approximately 25,000 light-years away, the site clearly shows the interaction of a supernova with a star-forming region. A team of radio astronomers led by Farhad Yusef-Zadeh of Northwestern University obtained the high-resolution image with the Very Large Array (VLA) radio telescope in New Mexico.

The team is particularly interested in the red dots shown along the outer rim of this shell. The dots mark the location of masers — the microwave versions of lasers. Masers are generally found only in star-forming regions.



Farhad Yusef-Zadeh (Northwestern Univ.), Doug Roberts (Univ. of Illinois, Urbana-Champaign), and Kevin Uchida (Max-Planck-Inst. for Radio Astronomy). Image taken at the VLA.

Eerie and violent, a supernova remnant smashes into a molecular cloud, leaving masers (red dots) in its wake.

In this instance, they show the signatures of shock waves in space that were created when extremely hot gas blew off a dying star, and then plowed into the very cold molecular cloud. According to many astronomers, when a supernova's shock wave collides with a molecular cloud, the shock wave condenses the gas, enabling it to gravitationally collapse into clumps that later turn into newborn stars.

Of particular interest to the astronomers, and apparently unique to the center of our own Galaxy, is an unusual magnetic filamentary structure called a "snake," shown in the upper right of the image. Yusef-Zadeh and collaborators discovered the prototype of these filaments (seven have been discovered to date). This snake appears to be interacting with a maser. More research with the VLA is planned to better observe the location where the snake crosses the supernova remnant.

Ground Zero for ALH84001?

Planetary scientist Nadine Barlow of the University of Central Florida has pinpointed a martian crater spawned perhaps by the same impact that launched meteorite ALH84001 to Earth. Last August a NASA team announced that ALH84001 contains possible signs of early martian life (see "Was There Life on Mars?" November 1996).

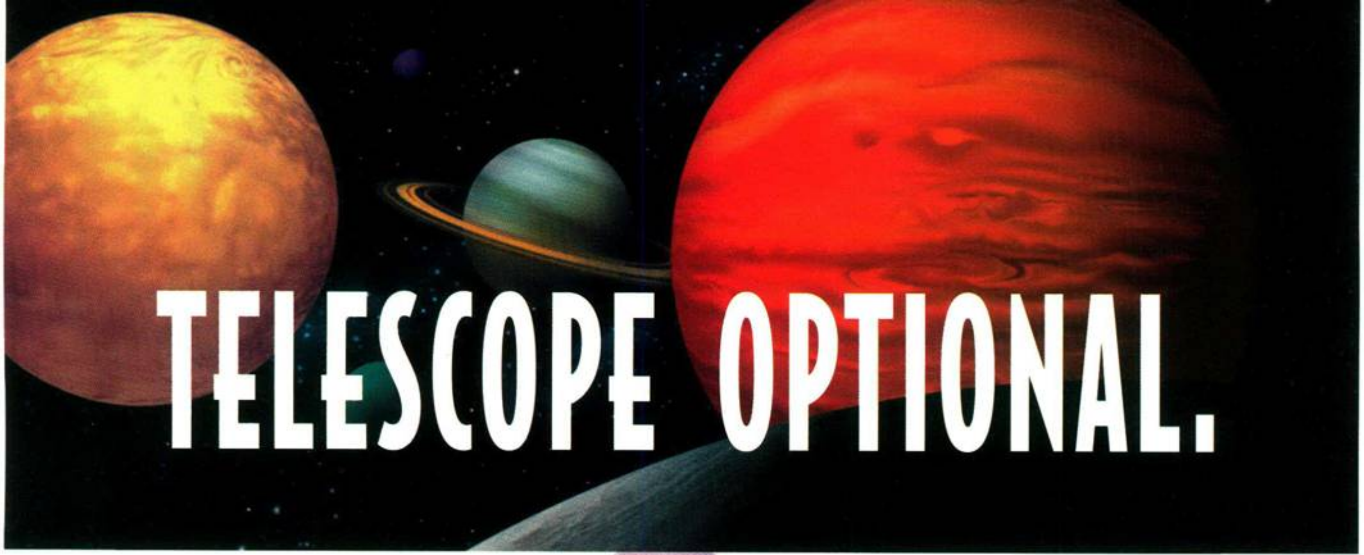
Barlow factored in several lines of evidence to narrow her search for the birth crater. One is the meteorite's 4.5-billion-year age. It points to an ancient area on Mars untouched by volcanism. Another is microscopic shock patterns locked in the old rock. They speak of nearby impacts that occurred long before the meteorite itself was blasted toward Earth. Factoring in these clues, Barlow concluded that ALH84001 came from the heavily cratered, ancient southern hemisphere of Mars.

NASA

The smoking gun? This 23 x 14.5 km crater just south of a dried-up river channel in Mars' southern hemisphere might be where the possible fossil-bearing meteorite came from.

Barlow next used computer models to get a rough idea of what the progenitor crater might look like. The genesis crater would look fresh, because astronomers figure the meteorite was blasted from Mars about 15 million years ago. A direct hit by a 100-kilometer-wide asteroid would have been big enough to blast debris off Mars, but Barlow found no large, fresh, circular craters in the southern hemisphere. However, a glancing blow by a smaller asteroid traveling at a low angle to the horizon, creating a more oval-shaped crater, would have done the job as well.

After scouring a 42,283-crater database, Barlow settled on one crater that fit all the criteria: an oval-shaped scar in the Sinus Sabaeus region, 14° south of the martian equator. The candidate lies in an



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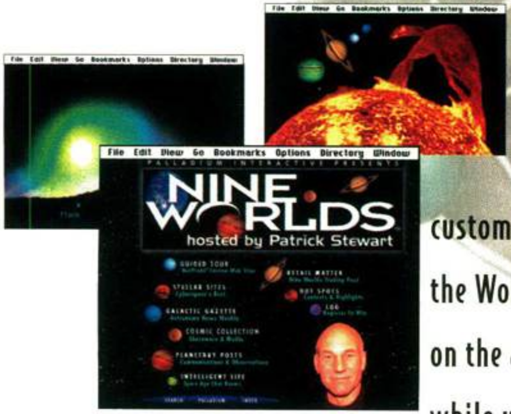

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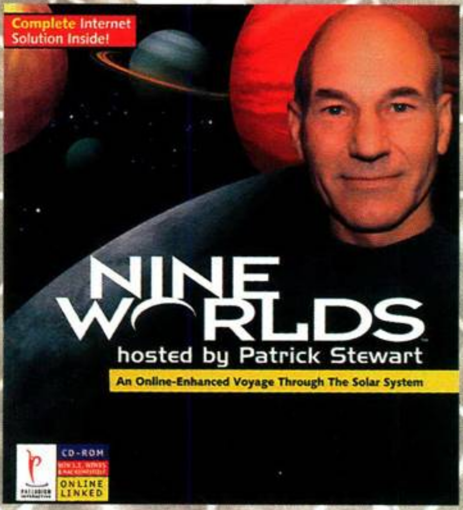
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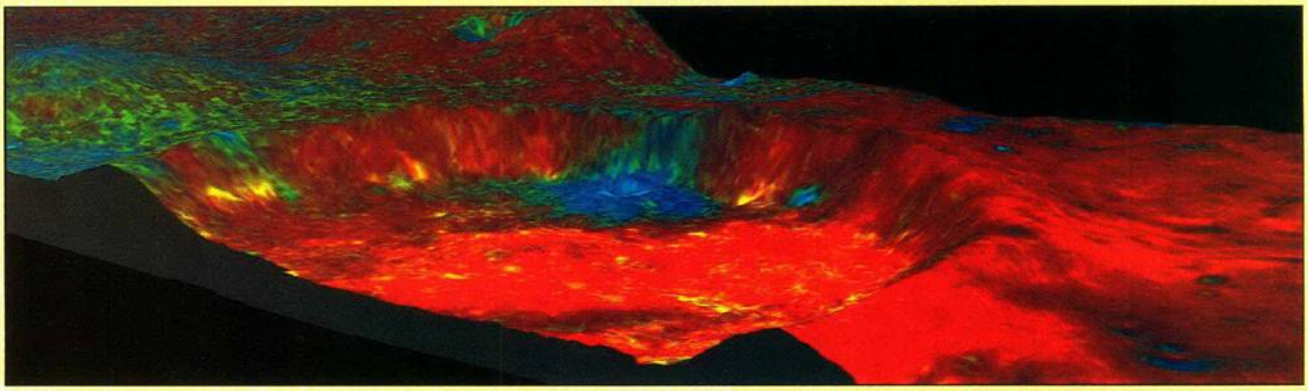


DLR (German Aerospace Research Establishment), Institute of Planetary Exploration

Marita Wählisch and her colleagues at the Institute of Planetary Exploration in Berlin, Germany, used 43 images taken by the Clementine spacecraft in May 1994 to assemble this topographical map of the lunar crater Kopff. The 42-kilometer-wide crater lies in Mare Orientale on the Moon's southwestern limb. Features only 100 to 200 meters across can be discerned. The crater's floor lies roughly 2 kilometers below the rim. The colors correspond to different chemical compositions. Scientists use maps like this to study the structure, mineralogy, and chemistry of Mare Orientale in unprecedented detail. This will help them learn more about such multi-ringed impact basins.

ancient crater field and, tantalizingly, just south of a dried-up water channel. Another less likely candidate, one not as oval but which sports a well-defined central peak, lies in Hesperia Planitia. NASA could use Barlow's work to target a sample-return mission in a search for signs of martian life, both past and present.

Carbon Monoxide Crashes the Party

Some astronomers might not admit it, but they really wish it wasn't there. The "it" is an enormous cloud of carbon monoxide gas. The "there" is quasar BR1202–0725, a quasar that's so far away that we see it as it existed less than 1 billion years after the Big Bang.

Two teams of astronomers, one based in Japan and the other in France, found the carbon monoxide cloud in close proximity to BR1202–0725, one of the most distant known objects in the universe. Carbon monoxide has never been seen so far away.

Why is this a problem? The carbon and oxygen that make up carbon monoxide weren't really supposed to have existed in large quantities so soon after the Big Bang. According to theory, the Big Bang cooked up lots of hydrogen and helium, but heavier elements like carbon and oxygen were forged later in the interior of stars.

So astronomers now have to explain why so much carbon monoxide existed soon after the Big Bang. The two teams think some galaxies must have formed very quickly out of the expanding debris from the Big Bang. These galaxies churned out an early generation of massive stars that exhausted their nuclear fuel in a hurry, spewing their carbon and oxygen debris when they died as supernovae. The discovery of other extremely distant galaxies (see "Hubble Spots Most Distant Galaxy?" AstroNews, November 1996) supports the view that galaxies were cranking out stars shortly after the Big Bang.

Homespun Jupiter has Bands

Jupiter's gigantic weather machine gets most of its energy from the planet's hot interior rather than from sunlight. So say Peter Olson and Jean-Baptiste Manneville, who duplicated Jupiter's banded structure using a 25-centimeter, spinning model of the planet in a Johns Hopkins University laboratory.

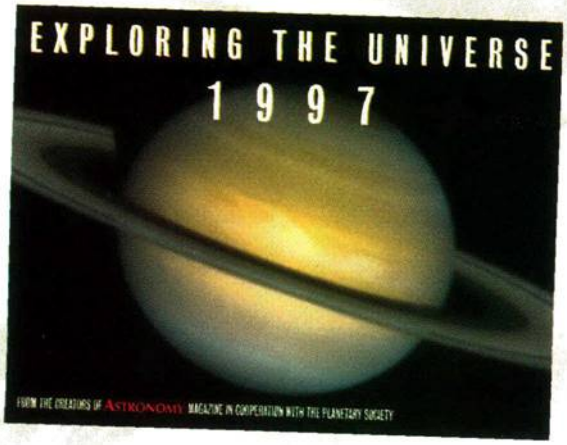
The duo re-created Jupiter's dynamic atmospheric circulation by placing water inside a sealed sphere installed with a temperature-controlled core. As the researchers raised the temperature within the sphere and spun it faster, dye in the water formed itself into distinct bands, not unlike what's seen on the real Jupiter. Next up in the modeler's list of things to simulate: a fast-moving jet stream that girdles Jupiter's equator.

Olson and Manneville reported their results in the August 1996 *Icarus*.

Hubble Detects Egg-Shaped Stars

Recent observations from the Hubble Space Telescope confirm that two old, gigantic stars, belonging to a special class of pulsating stars called Mira variables, aren't round but are instead egg-shaped. Mira variables are important because they preview the fate of our Sun five billion years from now.

One of the Hubble Space Telescope's Fine Guidance Sensors (FGS), normally used to accurately point the telescope, measured the angular diameters of R Leonis and W Hydrae. Ground-based instruments can't resolve either star's disk. But from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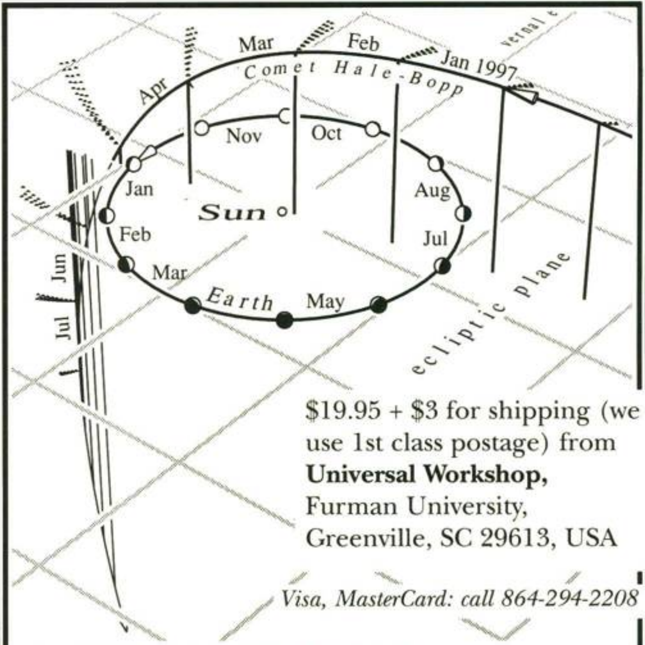

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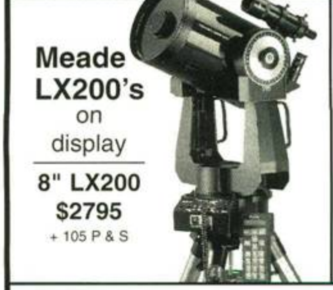
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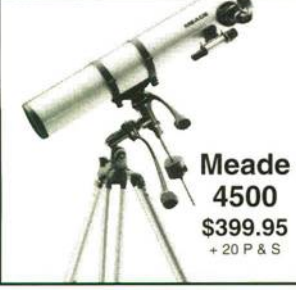
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its vantage point above Earth's blurring atmosphere, Hubble's FGS can resolve angular sizes only 1/100 of an arcsecond across, equivalent to detecting the width of a dime placed about 320 kilometers away.

The measurements show that R Leonis' apparent diameter is 70 by 78 milliarcseconds. That's equivalent to about 925 by 1,040 solar diameters along the star's short and long axis, respectively. W Hydrae has similar dimensions. If placed at the center of our solar system, both of these stars would extend to the orbit of Jupiter.

The observations were conducted by Italian astronomers Mario Lattanzi (Turin Observatory) and Ulisse Munari (Padova Observatory), and South African astronomers Michael Feast (Cape Town Univ.) and Patricia Whitelock (South African Astronomical Observatory).

Eros has Earth's Number

433 Eros is coming! With a diameter more than twice that of the Chicxulub asteroid, the impactor that killed off the dinosaurs 65 million years ago, 22-km-wide Eros might hit Earth in no less than 1.1 million years. All this thanks to the machinations of other planets in the solar system.

So says a paper published in *Nature* by mathematicians from the University of Pisa in Italy. They modeled how the orbit of Eros gravitationally interacts with Mars and, to a lesser extent, the outer planets. Presently the asteroid is just a near-Earth asteroid, one whose orbit lies close to Earth's. But three out of eight simulated encounters with the Red Planet changed Eros from a harmless near-Earth asteroid into a more menacing Earth-crossing asteroid. One encounter actually tweaked Eros into an orbit that intercepted Earth in just over one million years.

Coincidentally, an unmanned spacecraft is about to give humans a glimpse of our destiny. The NEAR (Near Earth Asteroid Rendezvous) probe goes into orbit around Eros in early February 1999 (see "NEAR Journey to a Far Asteroid," March 1996).

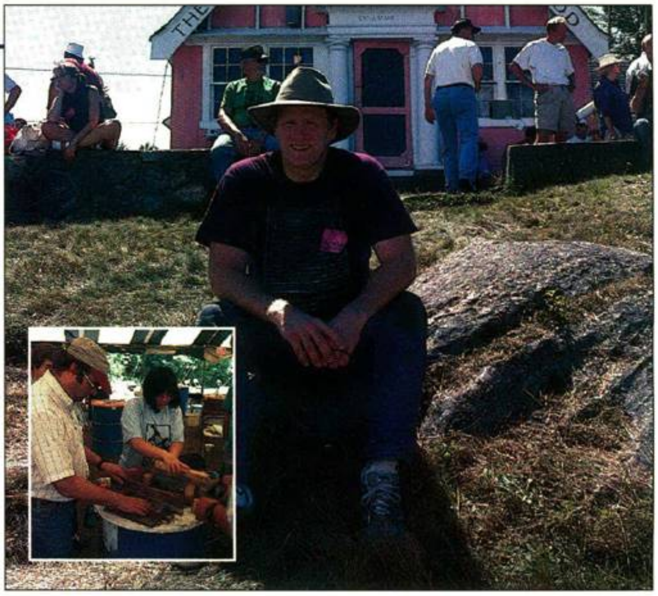
AMATEUR NEWS

Telescopes and Comets at Stellafane

Hundreds of backyard astronomers from New England and across the country flocked to Springfield, Vermont, last August 9–10 for the 61st annual Stellafane convention. The event, the nation's oldest and second largest gathering of amateur skygazers, featured a range of talks, an amateur telescope making workshop, competition for innovative telescope designs, and, when weather permitted, observing.

Intermittent rain showers disturbed the event on Friday the 9th before clouds broke up and allowed Breezy Hill, the convention site near Springfield, to begin drying out. Informal tent talks on Friday evening attracted a considerable crowd and included presentations on Comet Hyakutake by Bruce Gundlach and Richard Murphy, a question-and-answer session from well-known telescope maker John Dobson, a pitch for the Ulysses Comet Watch by Carolyn Collins-Peterson, a session on rebuilding a Springfield telescope by Paul Valelli, and a talk about stereo photography of comets by Dick Koolish.

Three talks highlighted Saturday, a day featuring partly cloudy skies. The theme was large telescopes — making optics, constructing an observatory, and using monster telescopes. The speakers were Mario Motta of Lynnfield, Massachusetts, Steve Dodson of Sudbury, Ontario, and John Vogt of Huntington, New York.

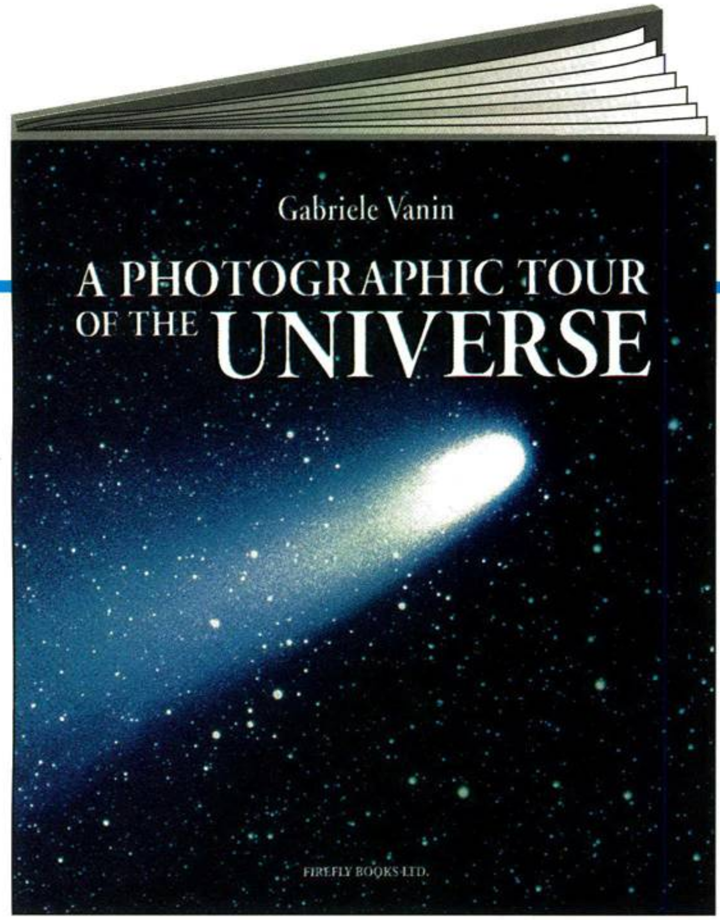


ASTRONOMY: David J. Eicher

Frequent ASTRONOMY contributor and well-known double star and variable star observer Glenn Chaple relaxes on Breezy Hill at the 1996 Stellafane convention. Inset: Mirror-making demonstrations by the Springfield Telescope Makers attracted crowds of onlookers.

The Saturday evening program featured an informal talk by John Dobson, inventor of the Dobsonian telescope, a presentation of awards for meritorious telescopes displayed on the Stellafane grounds, and an address on the search for extraterrestrial intelligence by Harvard University physicist Paul Horowitz.

— *David J. Eicher*



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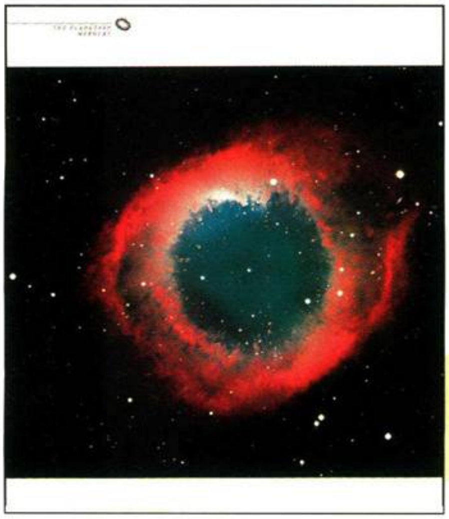

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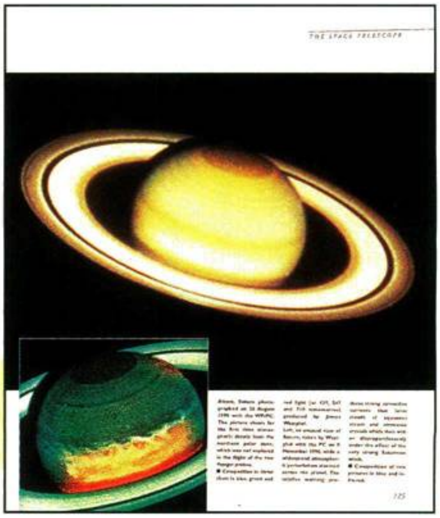

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AMATEUR NEWS

Dreams Come True at StarFest '96

Perfectly clear skies are every amateur astronomer's dream, and dreams came true at StarFest '96 held on August 8-12 at the River Place Campground in Mount Forest, Ontario. Organized by the North York Amateur Astronomers (NYAA), 800 people enjoyed perfect weather and fine speakers at Canada's largest star party, now in its 15th year.

ESA astronaut Claude Nicollier, veteran of three space flights including the mission to repair the Hubble Space Telescope, spoke about stargazing from the cabin of the Space Shuttle.

Participants re-lived the excitement of seeing last spring's Comet Hyakutake when Peter Ceravolo showed a color time-lapse video made from 800 images of the comet. Hyakutake's blue ion tail was vividly shown blowing in the solar wind.

A special feature was KidFest, an astronomy program for the younger participants. Kids engaged in a number of projects, such as building a scale model of the solar system.

Amateur astronomers exhibited a wide range of expertise during nightly observing sessions. Tom Bisque demonstrated the power of remote observing by controlling Mt. Wilson's 24-inch telescope in California.

Participants were treated to many of Terence Dickinson's images when he presented "The Lure of the Night Sky," and CCD imaging was prominent in the daily series of lectures which included the Advanced Observing Workshop (Jack Newton and Don Parker). All-sky images taken with a 16mm lens in Australia were projected inside a portable planetarium (Glen LeDrew), and the joy and magic of the night sky were covered in two sessions (Guy Nason and Tony Ward). Andreas Gada spoke on observing and photographing lunar eclipses. People also had a great time checking out the Swap Table, the Red-Light Cafe, an astrophotography contest, and vendors.

Plans are underway for StarFest '97. Details will be available next spring on the NYAA's Web site at http://www.unicom.org/~nyaa/nyaa0.htm.

— *Martin Ratcliffe*

Martin Ratcliffe

Many children at StarFest '96 learned about the science and hobby of astronomy by participating in an educational program called KidFest.

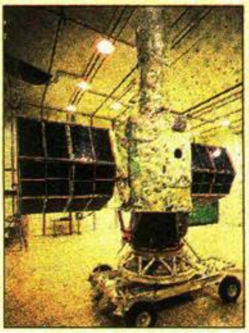
EVENT HORIZON

Yes, They're Voids

In the 1980s astronomers were astonished to find that galaxies string together in enormous chains that surround immense galaxy-less voids hundreds of millions of light-years across. Now it turns out that these voids are not only devoid of luminous matter, they're devoid of dark matter as well. Astronomers from the European Southern Observatory in Chile measured the velocities of 2,000 galaxies and determined where dark matter would have to be to account for the galaxies' velocities. It turns out that several voids didn't need any dark matter at all to explain these motions. The discovery means that dark matter, like visible matter, is not distributed evenly throughout the cosmos.

The Little Spacecraft That Did

After performing more than 100,000 observations over 18 years, the International Ultraviolet Explorer (IUE) satellite was turned off on September 30, 1996. Launched in January 1978, the orbiting observatory was supposed to operate just two years. NASA handed off control of the craft, still limping along on only one of six pointing gyroscopes, to the European Space Agency in October 1995. ESA said that funding constraints shaped their decision to shut down IUE.



NASA

R.I.P.: International Ultraviolet Explorer, January 1978 to September 1996

Clang!

The first collision in Earth orbit between two manmade space objects was recorded at Mission Control Center in Guildford, England. On July 24, 1996, the 50-kg French CERISE satellite suddenly tumbled end-over-end in its 700-km-high polar orbit. Later analysis showed that it collided with a piece of space junk at a speed of 50,000 km per hour. The suspected culprit is a 100-mm-wide fragment of an Ariane rocket. Controllers managed to regain control of CERISE.

Another Brown Dwarf

A team of astronomers led by Rafael Rebolo (Astrophysical Institute of the Canaries) has announced the third brown dwarf in the Pleiades. Using the 10-meter Keck Telescope in Hawaii, Rebolo's team found the spectral signature of lithium in this object, called Calar 3. Lithium is quickly burned up inside stars, so the presence of lithium means an object is not hot enough to be a star. The other two brown dwarfs, PPL 15 and Teide 1, also passed the lithium test. Rebolo's team estimates that Calar 3 has a mass of about 55 Jupiters.

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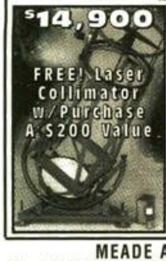

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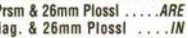

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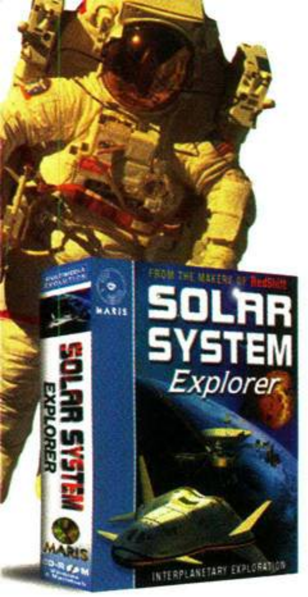

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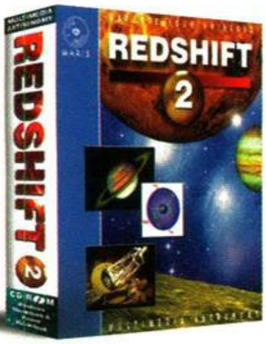

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TO KILL A GALAXY

THE MILKY WAY IS RIPPING APART A HELPLESS GALAXY IN THE CONSTELLATION SAGITTARIUS AND WILL SOON DEVOUR MILLIONS OF ITS STARS.

by Ken Croswell

Beware the Milky Way. The galaxy we call home is a giant far larger, brighter, and mightier than most other galaxies in the universe. Shining with the light of hundreds of billions of stars and shrouded in a lethal web of dark matter, the Milky Way can capture and annihilate luckless galaxies that stray into its domain. In fact, billions of stars that now contribute to the Milky Way's luster were actually born elsewhere, in galaxies this superpower tore to shreds long ago.

The most dramatic evidence yet of the Milky Way's immense power came in 1994, when three astronomers based in England — Rodrigo Ibata, Gerard Gilmore, and Mike Irwin — discovered a group of old stars traveling together in Sagittarius. The stars were the remains of a dwarf galaxy that had ventured too close to the Milky Way and was being pulled apart by its gravity.

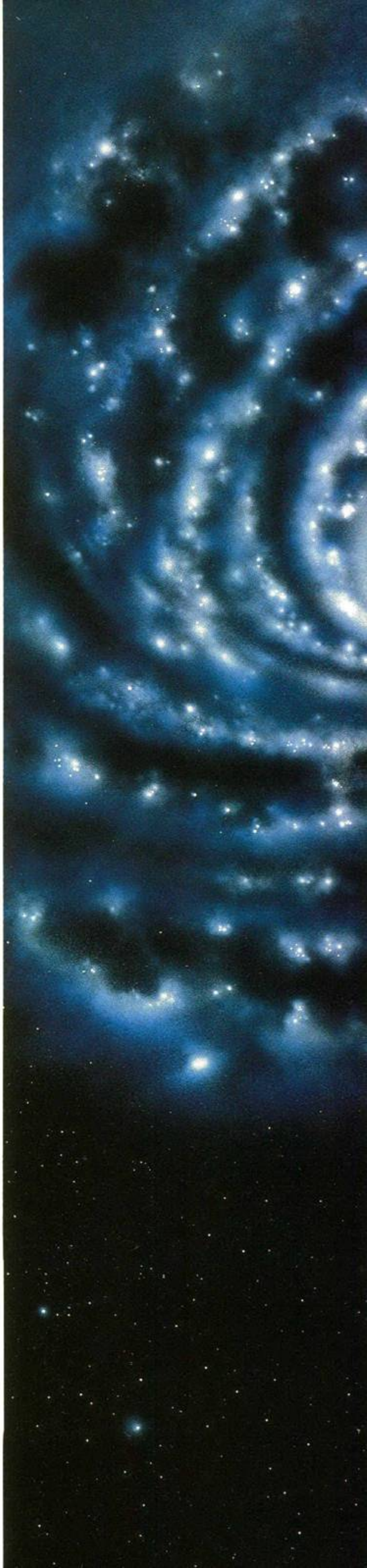
This nearby galaxy, or ex-galaxy to be more precise, eluded detection for most of the twentieth century because it lies on the opposite side of the Milky Way's center, which means that astronomers must view it through the Galaxy's star-packed central metropolis. In fact, the discovery of the Sagittarius dwarf was an accident, made as Ibata's team was studying stars near the galactic center. The dwarf's stars stood out from the rest because they traveled at a different speed.

Lying just 60,000 light-years from the heart of the Milky Way, the Sagittarius dwarf is not only closer to us than any other galaxy but it's also closer than the edge of the Milky Way's disk. It lies only twice as far from the galactic center as the Sun does. But the Sagittarius dwarf does not belong to the disk, because it is 20,000 light-years below the galactic plane. The Milky Way's gravity has so disrupted the small galaxy that its stars are now stretched over a 25,000-light-year-long region of space the shape of a cigar.

The death of the Sagittarius galaxy is more than just a warning to other nearby galaxies, like the Magellanic Clouds, of the grisly fate that awaits them. It also provides insight into how the Milky Way may have formed: by swallowing other galaxies and growing into a giant that, with Andromeda, now dominates the Local Group of galaxies.

The Galactic Empire

Even before astronomers discovered the Sagittarius dwarf, they knew the Milky Way ruled an empire containing at least ten other galaxies. These orbit our galaxy the way the Moon circles the Earth. The two brightest and best-known satellites of the Milky Way are the Large and Small Magellanic Clouds, which lie 160,000



The Milky Way's gravity shreds the nearby Sagittarius dwarf, leaving behind a loose, cigar-shaped collection of stars.

Mark Paternostro

John Shibley

The newly discovered dwarf lies hidden behind the Milky Way's rich star fields in Sagittarius.

and 190,000 light-years away respectively. Although the Magellanic Clouds are smaller than the Milky Way, they are not dwarf galaxies, for each harbors billions of stars and outshines most other galaxies in the cosmos.

At greater distances lie eight other satellite galaxies that are so dim they are called dwarfs. Most dwarfs contain just a few million stars and measure roughly a thousand light-years across. Astronomers spotted the first two, the Sculptor and Fornax dwarfs, in 1938, and the most recent in 1990, when a computer discerned an obscure dwarf in the constellation Sextans. The farthest dwarf satellite patrols the Milky Way's dark frontier 890,000 light-years away in Leo.

Some of these dwarf galaxies are extremely faint. The least luminous known galaxy in the entire universe is the Draco dwarf, which lies 250,000 light-years away. The combined light of all its millions of stars does not even equal the light given off by the single brightest star in the Milky Way. In fact, the Galaxy's most luminous star is four times brighter than the entire Draco dwarf.

Whether large or small, every satellite galaxy confronts the Milky Way's tremendous power. This power takes several forms. The most obvious is the Galaxy's strong gravitational pull, which lures galaxies toward it. The product of a mass having roughly a trillion Suns, this gravitational force keeps the satellites obeying the Milky Way's command as they orbit its center.

But any satellite galaxy faces a much more insidious danger. Once the Milky Way has snared a galaxy with its gravity, it moves in for the kill. This comes from the galactic tide, which tears galaxies apart. On Earth, tides occur because the Moon's gravity pulls more strongly on the side of Earth facing the Moon than on the opposite side, so the lunar tide tries, unsuccessfully, to tear Earth in two.

In space, a nearby galaxy experiences the same phenomenon, but in this instance, the tides can be fatal. Stars on the side of a dwarf galaxy facing the Milky Way's center feel a stronger gravitational force than those on the far side, so the stars get torn away from one another and the galaxy disintegrates (see "Galaxies Colliding in the Night," November 1996).

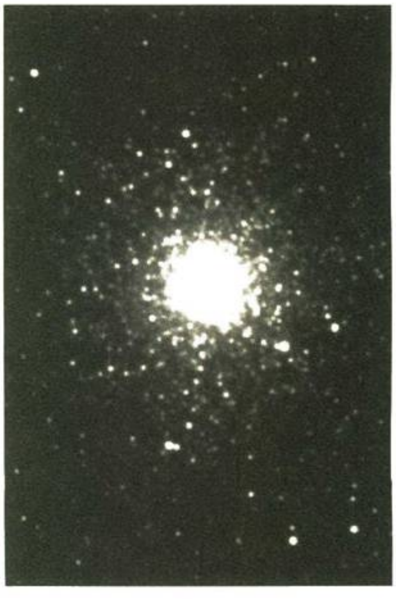
The strength of this tide depends brutally on distance: halve the galaxy's distance from the Milky Way's center and the tide becomes eight times more powerful. Dwarf galaxies are especially vulnerable to the Galactic tide because their stars are spread out and loosely bound to one another. Thus, as a helpless galaxy falls inward, the strength of the tide shoots up enormously and destroys the galaxy, splattering its stars into the Milky Way's halo, where they feed our Galaxy's ravenous appetite.

The Death of Sagittarius

The Sagittarius dwarf displays all the hallmarks of tidal disruption. Its stars are so spread out that they now owe more allegiance to the Milky Way than to one another, because they are no longer gravitationally bound to their peers. Unlike all the other dwarf satellites, which are smooth and uniform, Sagittarius is clumpy: Most of its stars conglomerate in two groups, one of which is several thousand light-years closer to the Milky Way's center. In other words, our galaxy's tide has literally torn the dwarf in two.

Before falling victim to the Milky Way, though, Sagittarius was a fairly substantial dwarf galaxy, comparable to or even larger than Fornax, the Milky Way's greatest dwarf satellite. Fornax emits more light than the other seven dwarfs combined. In addition, unlike those dwarfs, Fornax has globular star clusters — five of them — whereas about 150 are known in the Milky Way.

Globular cluster M54 lies at the center of the Sagittarius dwarf. It's the second most luminous globular orbiting the Milky Way.

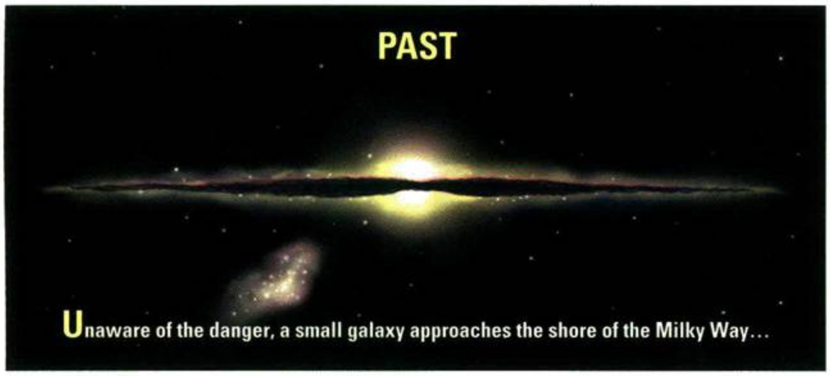


Ata Sarajedini (NOAO) and Andrew Layden (McMaster Univ.)

A typical globular cluster houses hundreds of thousands of stars in a space about a hundred light-years across. Globulars are vital to the study of the Milky Way's ancient past because they are among the oldest objects in the Galaxy. They therefore preserve a record of what our galaxy was like long ago, as it was just forming, and astronomers frequently use them to trace how the Milky Way originated.

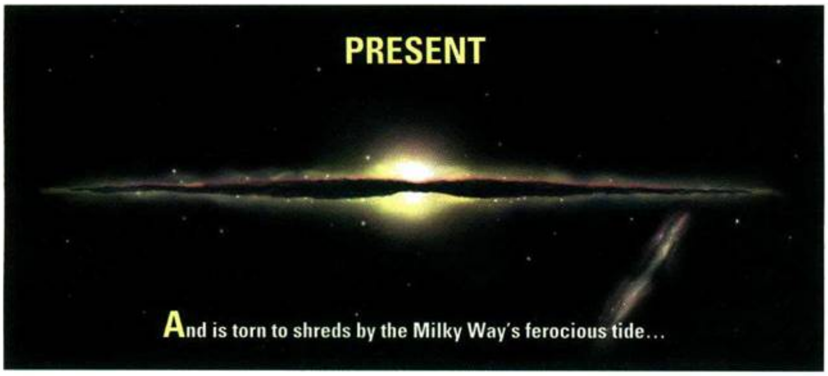
The Sagittarius dwarf galaxy apparently delivered at least four globular clusters to the Milky Way. One of them is even prominent enough to be a Messier object. Globular cluster M54 lies just west of Zeta Sagittarii, the southernmost star in the handle of the Sagittarius teapot. M54 is the second most luminous globular cluster in the entire Galaxy, after Omega Centauri. It lies in the densest region of the Sagittarius dwarf and matches the dwarf's distance and velocity. Three other globulars, all much fainter — Arp 2, Terzan 7, and Terzan 8 — reside beyond the eastern edge of the Sagittarius dwarf but also share its distance and velocity. These, too, were likely brought to the Milky Way by the Sagittarius dwarf.

That Sagittarius had globular clusters suggests that it, like Fornax, was a large dwarf. So does Sagittarius' metallicity — its abundance of elements heavier than hydrogen and helium — which by dwarf standards is high. Heavy elements are forged by stars from lighter elements and spewed into a galaxy when the stars die. Therefore, the bigger a galaxy, the higher its metallicity, both because the larger number of stars creates a larger abundance of heavy elements and because the galaxy's greater gravity holds on to debris cast off by dying stars.



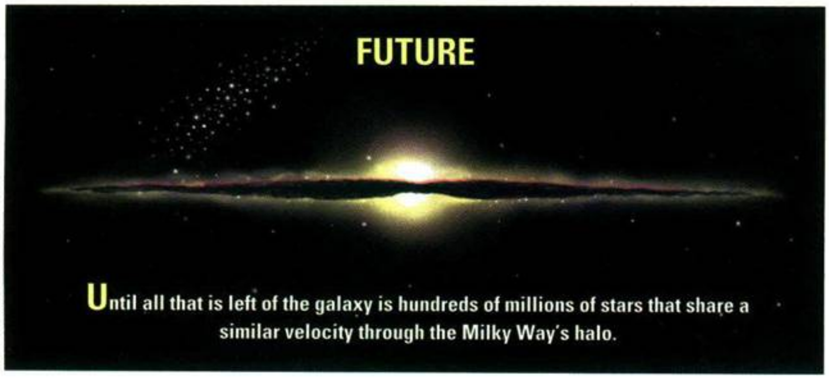
PAST

Unaware of the danger, a small galaxy approaches the shore of the Milky Way...



PRESENT

And is torn to shreds by the Milky Way's ferocious tide...



FUTURE

Until all that is left of the galaxy is hundreds of millions of stars that share a similar velocity through the Milky Way's halo.

ASTRONOMY: Elisabeth Rowan

Metallicity is literally a matter of life or death, because living beings require heavy elements such as carbon and iron. Giant galaxies, like the Milky Way and Andromeda, have such high metallicities that life can arise within them. In contrast, the smallest dwarf galaxies have extremely low metallicities, meaning they probably don't contain enough raw materials for life. For example, the puny Draco dwarf has a metallicity of only 1 percent of the solar value, and even Fornax, the largest dwarf satellite, has a metallicity of just 4 percent.

The Sagittarius dwarf appears to have a metallicity higher than that of Fornax, somewhere between 10 and 30 percent, which suggests that prior to its destruction Sagittarius was larger than Fornax. But once it ventured too close to the Milky Way, even Sagittarius could not withstand the Galaxy's deadly tide. A billion years from now, all that will be left is a bunch of stars in the galactic halo that share the same velocity around the Milky Way's center.

A Killer of a Galaxy

The destruction of Sagittarius is a tragedy for one small galaxy but offers great insight into how our own Galaxy originated. In 1962, Olin Eggen, Donald Lynden-Bell, and Allan Sandage proposed that the Milky Way formed from a single huge ball of gas that rapidly collapsed and gave birth to the oldest stars, those in the Galaxy's halo. This gas then collapsed into a disk, where it gave birth to more stars, including the Sun. According to Eggen, Lynden-Bell, and Sandage, this process was so swift that all halo stars have nearly the same age.

The first serious challenge to this view arose in 1978, when Leonard Searle and Robert Zinn proposed that the Galaxy's origin had been far more chaotic. According to Searle and Zinn, much of the Galaxy's halo came from

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galaxies that the Milky Way had captured. In the years since, astronomers have found conflicting evidence — some supporting Eggen, Lynden-Bell, and Sandage, some supporting Searle and Zinn — and today many astronomers believe that both pictures are necessary to fully understand the Galaxy's formation.

The Sagittarius dwarf shows the Searle and Zinn scenario in action. During the Milky Way's 15-billion-year lifetime, it may have captured galaxies just like the Sagittarius dwarf, giving our galaxy many of the stars we see today. According to this view, the satellite galaxies that today orbit the Milky Way are the few survivors of this process. They are metaphorically equivalent to asteroids and comets, objects that were not gathered up to form the planets when the solar system was born 4.6 billion years ago.

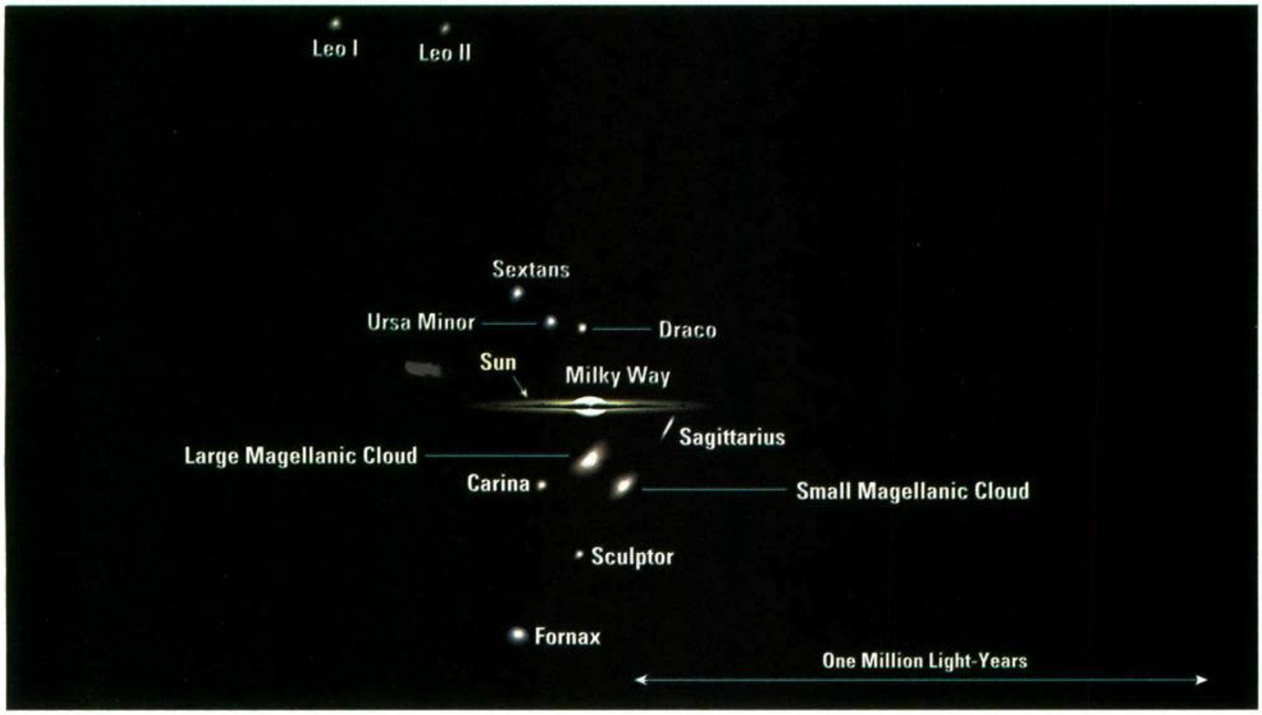
Goodbye to Galaxies

What of the future? For Sagittarius, it is bleak indeed. Only in the loosest sense is it really a galaxy anymore, for its stars are no longer gravitationally bound to one another. Over the next billion years, its stars will continue to spread out and the object will lose what little integrity it still possesses, the stars' similar metallicity and velocity being the only relics of the galaxy's past existence. Astronomers have seen other groups of stars moving through the halo with similar metallicities and velocities. These moving groups may be the remnants of galaxies that in the past crashed on the galactic shore.

The Milky Way will continue to demolish other galaxies. Bright though they now are, the Magellanic Clouds face exactly the same fate as the Sagittarius dwarf. In fact, because they are so massive, they face an additional danger, known as dynamical friction. Surrounding the Milky Way's bright, pancake-shaped disk is a huge

Two of the Milky Way's satellite galaxies: Leo I (upper left) is one of the smallest, and the Large Magellanic Cloud (below) is the largest.

Luke Dodd



ASTRONOMY: Elisabeth Rowan

halo of dark matter where most of the Galaxy's mass resides (see "The Dark Side of the Galaxy," October 1996). The total extent of the dark halo is unknown, but the Magellanic Clouds, as well as the Sagittarius dwarf, probably lie within it. As these satellite galaxies plow through the dark matter, they are slowed down by its gravity, rather like a celebrity moving through a throng of fans. This process robs a satellite galaxy of its orbital energy and makes it fall closer to the Milky Way's center. Although a satellite galaxy may try to scurry away, it will be unable to travel as far as it first did. The dark halo is a galactic-scale spider's web that traps galaxies like the Magellanic Clouds.

The more massive the satellite galaxy, the greater the dynamical friction. For Sagittarius, dynamical friction was fairly small, but for the Magellanic Clouds it is much stronger. As they travel through the Milky Way's dark halo, dynamical friction is dragging them in. As a result, tidal effects will increase and will eventually rip the galaxies apart. Already the Milky Way has extracted from the galaxies a long tail of gas that stretches some 300,000 light-years through the dark halo.

When the Milky Way swallows the Magellanic Clouds in a few billion years, the death of these galactic companions will be far more spectacular than that of Sagittarius, not only because the galaxies are much larger, but also because they contain clouds of gas and dust. When these clouds hit those in the Milky Way, they will trigger the birth of huge numbers of stars, and our galaxy may shine brighter than it ever has before. After the fireworks die down, some of the nearer dwarf satellites — such as Draco — may get reeled in, and the Milky Way may even snare galaxies that are now roaming freely through intergalactic space.

These events all testify to our galaxy's enormous power. Far larger, brighter, and mightier than most other galaxies, the Milky Way has probably swallowed dozens, perhaps hundreds, of galaxies during its long life. The Milky Way is now so huge that its many stars — some indigenous, others captured — have produced a high abundance of the life-giving elements that we require. Brutal though it may seem, the Galaxy's cannibalism may have allowed the Milky Way to create the living beings that have begun to comprehend its own violent history. □

The Small Magellanic Cloud is the second largest satellite galaxy in the Milky Way's empire. Globular cluster 47 Tucanae lies to the right.

Luke Dodd

Frequent contributor Ken Croswell is the author of The Alchemy of the Heavens *(Doubleday/Anchor), a recent book that explores our Galaxy, its origin, and its evolution.*

The Lone Astronomer: Gérard de Vaucouleurs

His theories, once viewed as controversial, are helping shape the way astronomers view the structure of the universe.

by Robert Tindol

Gérard de Vaucouleurs was sometimes called the "Lone Astronomer." The nickname is a playful reference to the Lone Ranger and, further, to de Vaucouleurs having spent 35 years in Texas, which culturally is about as far removed from his native Paris as one could imagine.

But if anyone could be said to have persevered when the going got tough, all the while maintaining his savoir faire, it was de Vaucouleurs. His death in September 1995 sent ripples of grief throughout professional and amateur astronomy. In both areas, the Lone Astronomer was greatly admired and respected.

De Vaucouleurs is perhaps best known for his strong advocacy over several decades of two major ideas that only recently have come into acceptance: The Milky Way is a part of a local supercluster, and the Hubble Constant is fairly high and the universe, consequently, younger than once thought. It was primarily for his work in these two areas — and his steadfast refusal to budge when others felt that the evidence was unconvincing — that he earned his reputation for controversy.

A Life of Astronomy

De Vaucouleurs was born April 25, 1918, in Paris. When he was only 15, he gave presentations to the Astronomical Society of France on the Sun, the Moon, an eclipse, various occultations, and photography of objects such as Mars and the Pleiades. By the next year, he was presenting new observations of other planets based on work with his 75mm refractor. By age 19, he was heavily involved in the mathematics of astronomy.

In 1939 he began a long association with Julien Péridier, a wealthy amateur astronomer who maintained a private observatory in Le Houga. De Vaucouleurs served as a professional astronomer in Péridier's employ during the occupation years of 1941 to 1943, after which he returned to Paris and worked on his dissertation at the Sorbonne.

In 1944 he married Antoinette Piétra, also a science student at the University of Paris. Thereafter, the de Vaucouleurses worked together in a myriad of research areas, with Antoinette concentrating on spectral studies in the early years and on galaxies once they came to America.

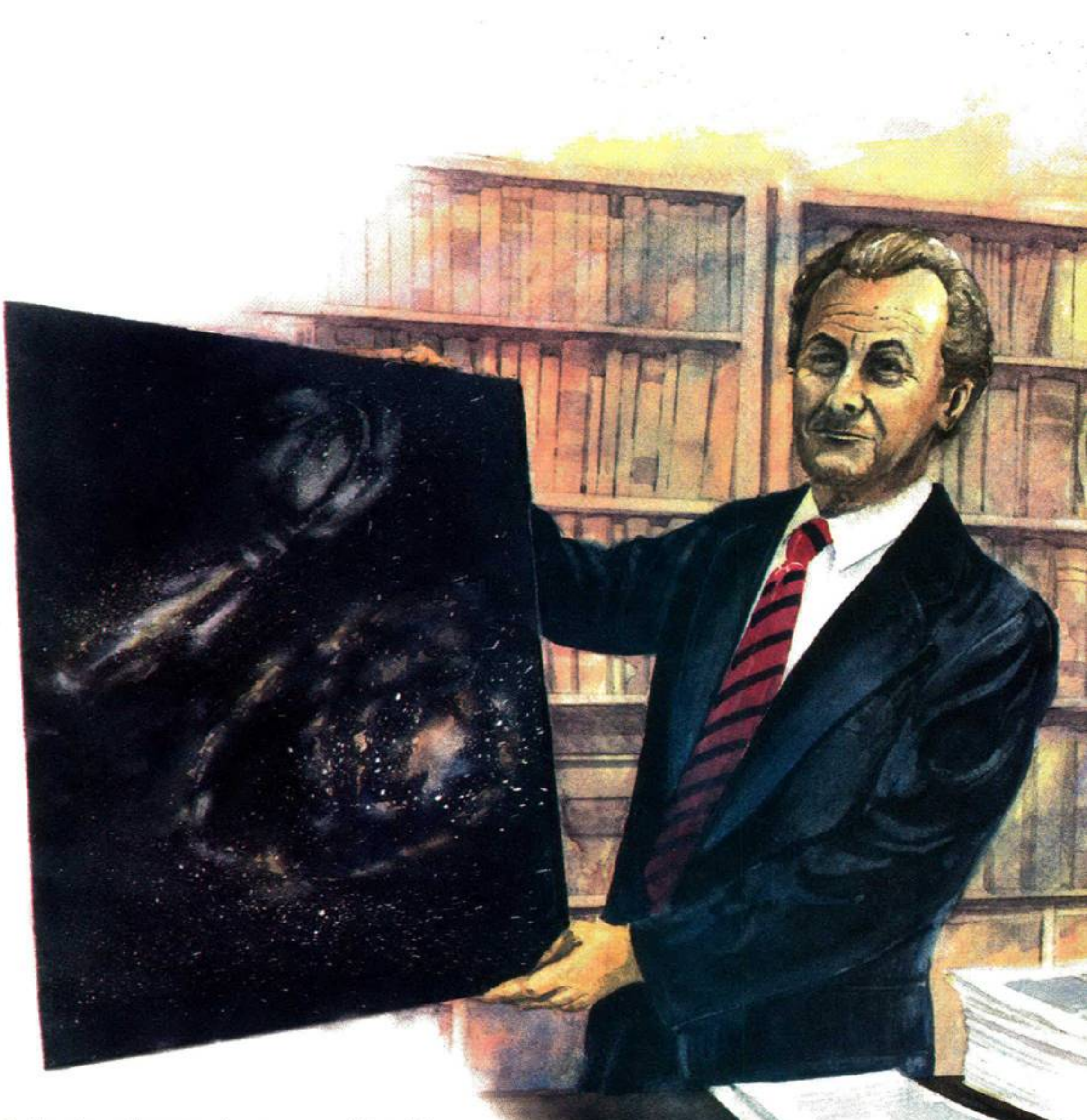
De Vaucouleurs finished his doctorate in physics at the Sorbonne in 1949, during which time he published the now-famous $r^{1/4}$ law. Inspired in part by his longstanding interest in astrophotography, the law provides a description of the surface brightness of elliptical galaxies as well as the bulges of lenticular and spiral galaxies.

Once Gérard and Antoinette had finished their training at the Sorbonne, they moved to London where they produced a BBC program on astronomy. The following year they went to Australia to work at the Mt. Stromlo Commonwealth Observatory. This was where de Vaucouleurs first began work on the belt of galaxies that runs approximately perpendicular to the Milky Way and which is now known as the Local Supercluster. Antoinette, meanwhile, continued her spectrographic work, and in 1957 published the first quantitative spectral and luminosity data on 366 stars in the Southern Hemisphere. Her husband also found time to pick up a second doctorate at the Australian National University.

De Vaucouleurs began working on the Local Supercluster when he noticed in the early 1950s that there seemed to be a "Milky Way of galaxies" that "could be traced all around the sky in both hemispheres," he wrote in 1980. "It seemed obvious that unless improbable chance encounters had brought together a number of independent clusters and clouds of galaxies, this was evidence of a flattened supersystem of galaxies — a Supergalaxy — within which our own galaxy and the Local Group were situated, rather far from the center."

Thus began our knowledge of the Local Supercluster. And though the work is now generally accepted, as late as 1976 de Vaucouleurs was still finding himself defending the decades-old work at professional astronomical meetings.

Immigrating to America in 1957, the de Vaucouleurses spent a year or so at the Harvard College Observatory and at the Lowell Observatory in Arizona. In 1960, they assumed positions at the University of Texas at Austin, an association that would see them through the remainder of their careers. At UT, de Vaucouleurs was instrumental in building the department with the late Harlan Smith, himself a popular, maverick astronomer whose reputation continues to grow. In a commemorative article in the book *A Life for Astronomy*, published in honor of de Vaucouleurs' 70th birthday, Smith wrote that his longtime colleague was a competent "photographer, optician, instrumentalist, librarian, teacher, raconteur, philanthropist . . . yes, and scientist too." Smith also noted that de Vaucouleurs was "a rare person, able to accomplish virtually anything he sets his mind to."



Les Thompson

A Younger Universe

By the early 1970s, de Vaucouleurs was involved with developing a particularly rigorous approach to the cosmic distance scale. He began deriving a rather high value for the Hubble Constant, which is the relative speed with which everything in space appears to rush away from everything else. He argued that the high density of matter in a supercluster makes determinations of the Hubble Constant problematic in that local gravity complicates the measurement of redshifts of nearby galaxies. Looking at redshifts a few billion light-years farther out makes local effects negligible but de Vaucouleurs also cautioned that imprecisions in determining distances locally would result in imprecisions farther out.

The debate on the Hubble Constant has raged for years, but a recent spate of studies points to a comparatively high value. Most astronomers today aim a bit lower than the 100 kilometers per second per megaparsec that de Vaucouleurs proposed, but very few will go as low as the 45 that has long been advocated by some cosmologists.

Later Years

Antoinette de Vaucouleurs died in 1987; colleagues say her death was a crippling blow for her husband. Only 65 when she died, she left behind a number of studies on planetary, stellar, and galactic spectroscopy, several papers on redshifts of various galaxies, a general catalog of photoelectric magnitudes, and a catalog of visual and infrared photometry of galaxies. In addition, she was listed as a coauthor in 45 of her husband's papers and books.

All told, de Vaucouleurs wrote or cowrote 31 books on astronomy, contributed to another 23 books, published 13 book reviews, wrote 363 technical articles on a huge variety of topics, and authored 87 nontechnical articles for the general public and amateur astronomers.

A fuller biography would have to include his groundbreaking work on mapping Mars and several other important endeavors, but it is his early description of the Local Supercluster, his refinement of methods used to ascertain extragalactic distances, and his consequent work on the Hubble Constant that are of prime interest today.

De Vaucouleurs dabbled little in theory, preferring experimentation and observation. But when cosmologists are finally comfortable with a model of the universe's origin, they will undoubtedly owe a debt of gratitude to the Lone Astronomer who for decades strove to understand the structure of the universe. ☐

Robert Tindol is a science writer living in Austin, Texas.

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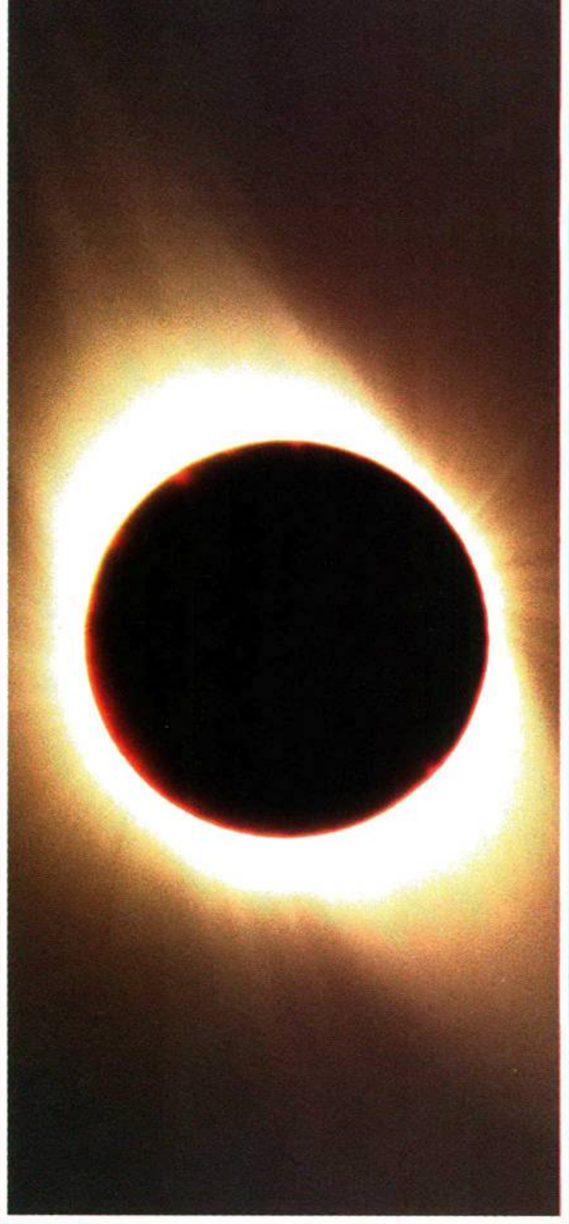

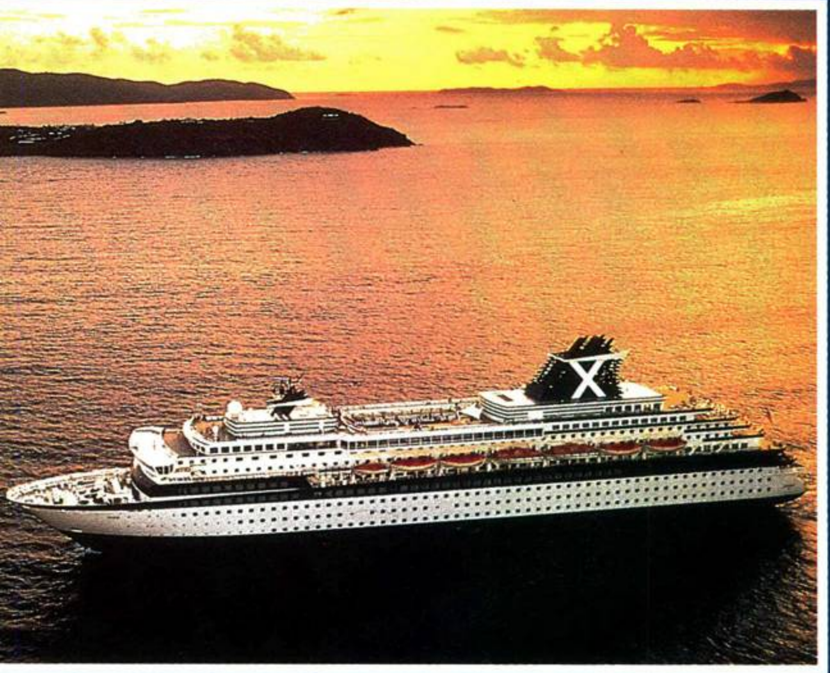

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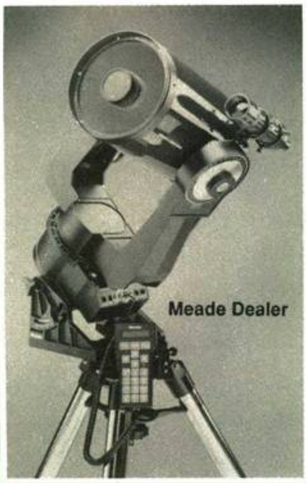

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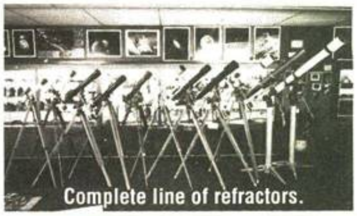

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Hui Yang (Univ. of Illinois), Jeff J. Hester (Arizona State Univ.), and NASA.

llar Nursery

Brilliant infant suns blowing a cavity inside their stellar nursery are revealed in a new Hubble Space Telescope photograph.

by Patti A. Kurtz

This is one nursery where you won't want to spend your leisure time admiring and cuddling the dazzling newborns. The infants here are simply too hot to handle and you'd be wise to leave them to their destinies of never-ending stress.

Like a lantern in a cavern, more than 200 hot stars illuminate the gaseous walls of NGC 604. The stars located at the blazing heart of this giant emission nebula are each more massive than the Sun (15 to 60 solar masses), and heat the nebula to temperatures of 10,000° kelvins, making the gases fluoresce brightly.

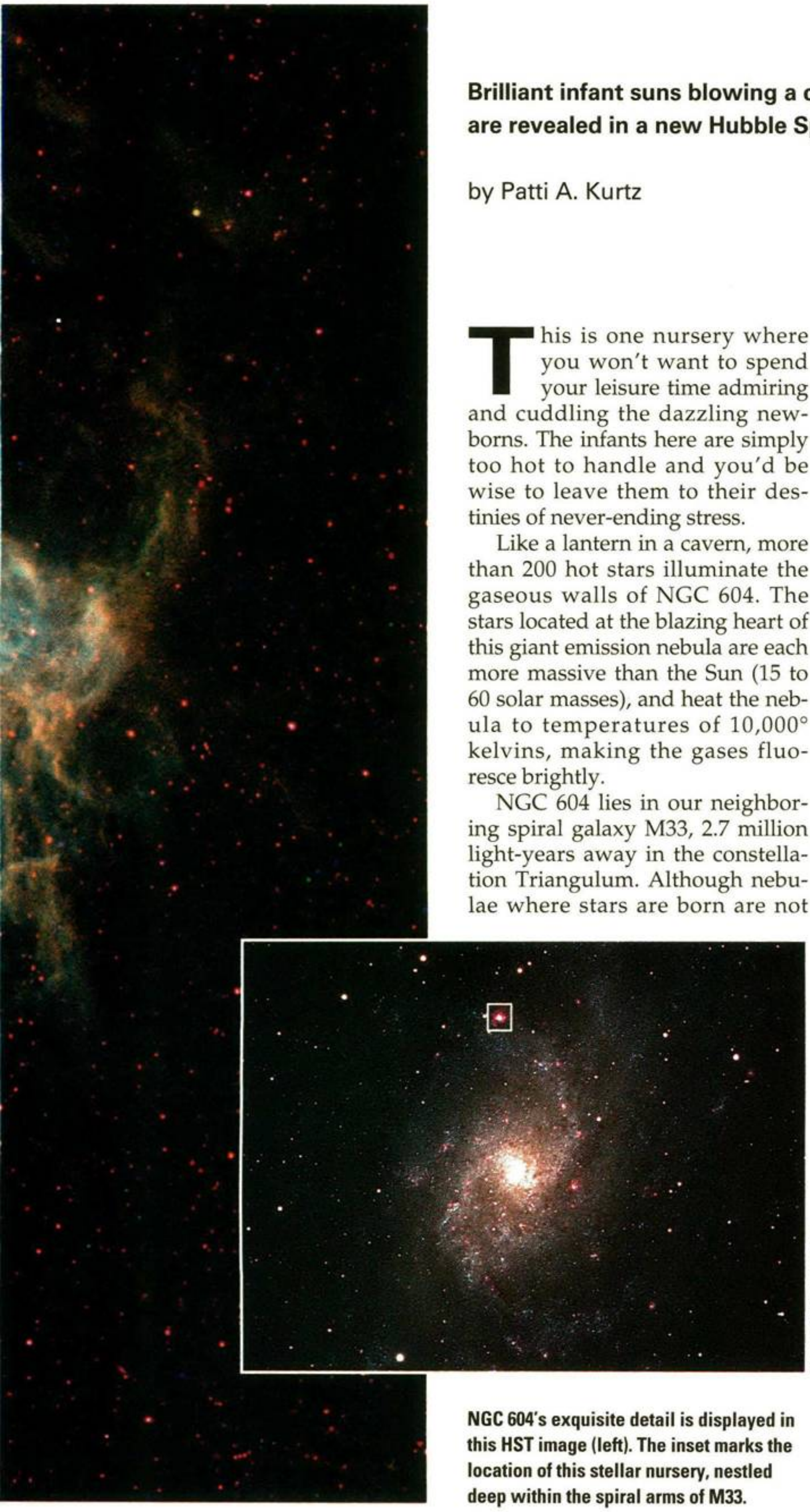
NGC 604 lies in our neighboring spiral galaxy M33, 2.7 million light-years away in the constellation Triangulum. Although nebulae where stars are born are not uncommon in galaxies, the sheer size of NGC 604 sets it apart — nearly 1,500 light-years across. It's one of the largest emission nebulae known in the universe.

M33 (NGC 598), also known as the Pinwheel Galaxy, is a loosely wound spiral (Hubble classification type Sc). It is the most distant spiral in the Local Group of galaxies, the tiny cloud of galaxies that contains the Andromeda Galaxy and our own Milky Way.

Hui Yang of the University of Illinois and Jeff J. Hester of Arizona State University used the Hubble Space Telescope's Wide Field and Planetary Camera 2 to image the nebula on January 17, 1995. In order to study the physical properties of the hot gas, separate exposures were taken in different colors of light and then combined to make this detailed color image.

By studying the physical structure of this giant nebula, Yang and Hester may determine how clusters of massive stars affect the evolution of the interstellar medium of the galaxy. NGC 604 is a classic inward-out emission region in that the dense material in the center formed stars first, creating a hollow in the nebula's center. The cavity was deepened by the intense winds blowing from these hot young stars.

The immense size of NGC 604 allows it to be studied in such detail in spite of its considerable distance. □

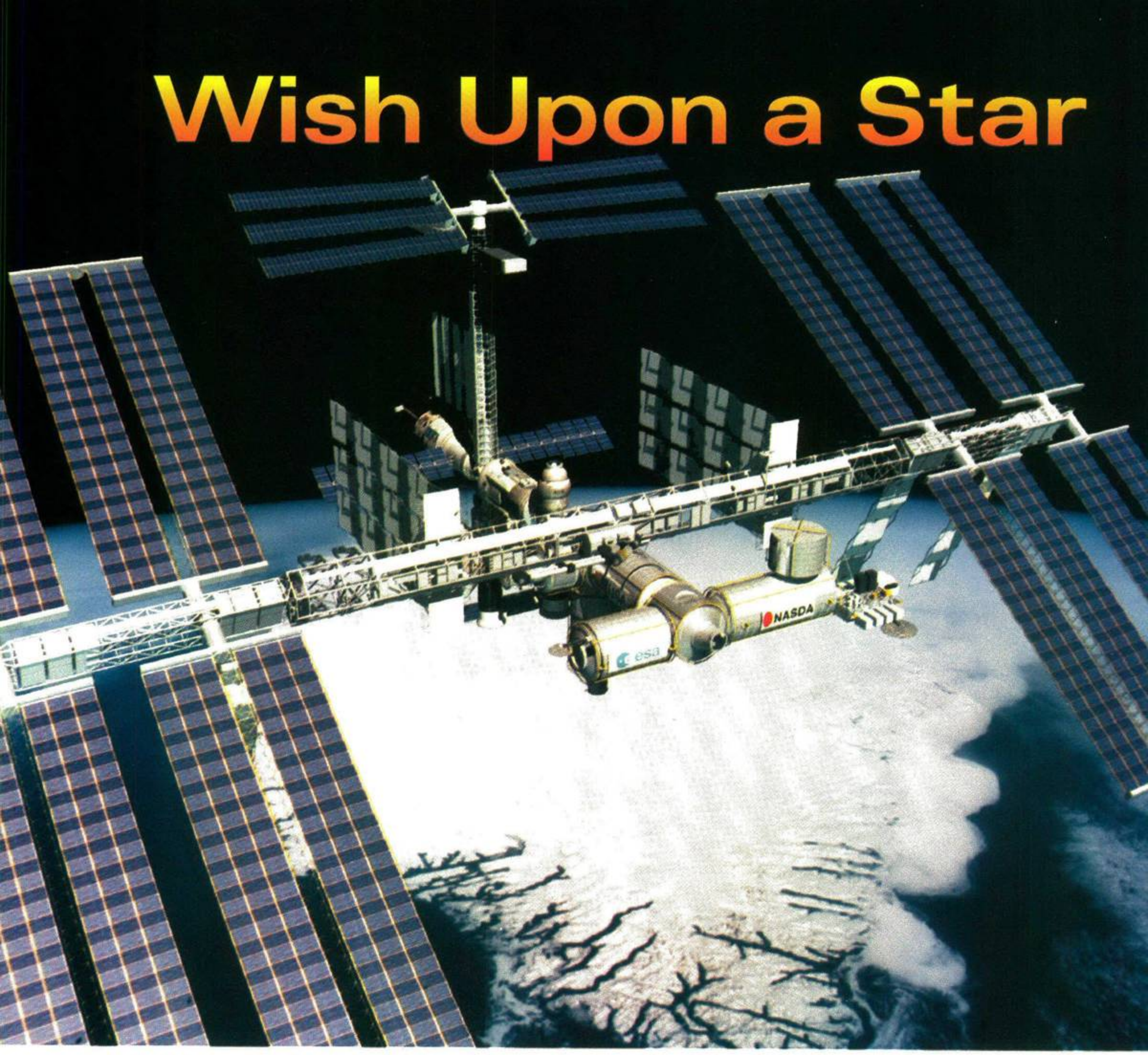


Tony and Daphne Hallas

NGC 604's exquisite detail is displayed in this HST image (left). The inset marks the location of this stellar nursery, nestled deep within the spiral arms of M33.

Patti A. Kurtz is assistant editor of ASTRONOMY *and an avid observer of nebulae.*

Wish Upon a Star



NASA

The Space Station floats serenely above Earth in its completed, fully operational state. Although current plans don't call for doing any astronomy, several small projects would enhance our knowledge.

The International Space Station could play an important role in astronomical research — if we want it to.

by S. Alan Stern

It's almost Christmas, but the workload on-orbit is just as intense as usual: materials processing, medical experiments, observations of Earth. But for the three American astronauts aboard the space station, almost one-third of their work concerns astronomy. This month they will use their sophisticated solar observatory to explore coronal holes, employ cameras to make ultraviolet images of an unusually bright comet approaching from the Oort Cloud, and go outside the station to harvest cosmic dust collectors.

It is December 1973. Yes — 1973. And the astronauts are aboard Skylab.

That was then, this is now. By the late 1990s, NASA's long-planned and long-awaited successor to Skylab will be flying. Officially called the International Space Station, this new facility will provide a host of capabilities Skylab's designers could only have dreamed of.

The International Space Station will support a crew of six at all times, but will have a capacity of 15 when the shuttle is docked. Its battery of solar arrays will generate 92 kilowatts of electricity (enough to power roughly one hundred homes), half of which will be available for experiments. It will feature at least six research laboratories supplied by the United States, Europe, Russia, and Japan. And it will be big: The International Space Station will stretch more than 100 meters across, weigh more than 400 tons, and contain over 1,200 cubic meters of pressurized volume. It is designed to operate at full staffing for at least 10 years.

The enterprise is breathtaking in both concept and scope. No less than 17 countries are involved. It will require 36 American and Russian launches to assemble the hardware in orbit, and then dozens more to regularly resupply it with crew, food, fuel, water, and research gear. No less than $30 billion will be spent before it is completed. Unfortunately, however, there are no plans to place astronomical instruments aboard the new Station.

Oil and Water

NASA literature succinctly summarizes the research goals of the Space Station. Simply put, it is to "create a permanently orbiting science institute capable of performing long-duration research in the materials and life sciences in a nearly gravity-free environment." How did materials and life sciences become the twin research foci of the Space Station? There are a number of threads to this story, but two stand out, in particular.

First, and probably foremost, NASA was forced to pare back its Space Station ambitions dramatically between 1984 and 1992. In those eight years, the Station project suffered no less than six major redesigns, each mandated by a budget-conscious Congress. And with each redesign, important capabilities were lost. With this loss in capability, NASA correctly recognized that the Station would have to focus on a much narrower range of research goals. After all, a Station that did many things marginally would be less useful than one that did a few things superbly.

Thus as budgets dwindled, NASA focused the Station on experimental sciences that both required low gravity and benefited from the presence of a human crew. As a result, NASA deleted from the Station's agenda several research disciplines, including astronomy, in favor of some better-fitting laboratory science fields, like biotechnology, human physiology, low-gravity combustion research, and materials science.

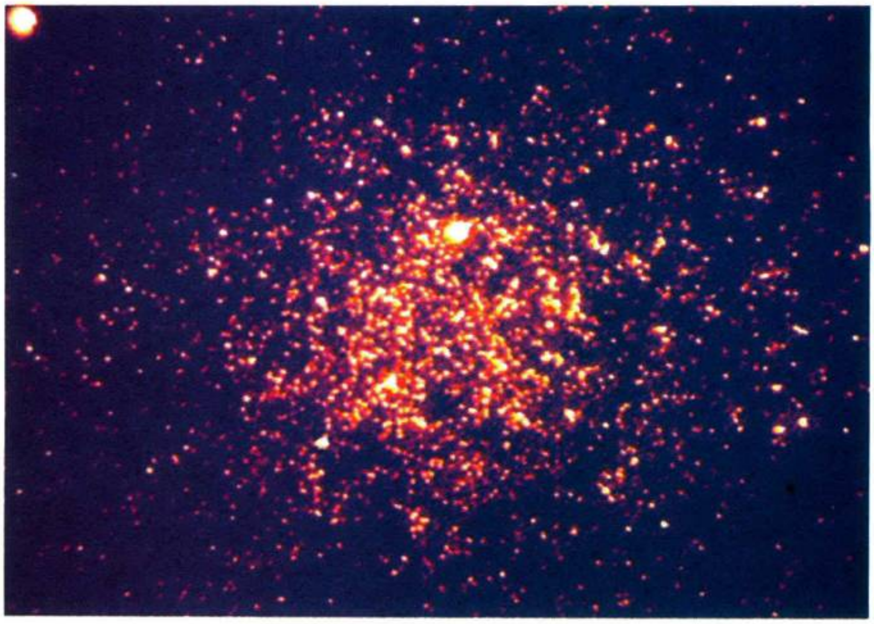
Coupled with this, astronomers themselves found or created a rationale for leaving their boat at the dock when the Station's voyage begins. They raised valid, though not insurmountable, technical concerns. These included the possibilities that sensitive optics would be contaminated by the effluents from the Station and the various spacecraft that supply it, and the incessant jitter humans and their life support systems (pumps, valves, vents, and such) would wreak on finely pointed telescopes. Some astronomers also complained of cost, fearing that the expense of man-rating their experiments would make them too expensive to fly on the Station, as happened with some shuttle experiments. It probably didn't help either when many astronomers and their major professional organization, the American Astronomical Society, publicly supported attempts to cancel the Station in 1991 and 1992.

NASA has focused the Station on materials and life sciences, both disciplines that require low gravity and benefit from a human crew.

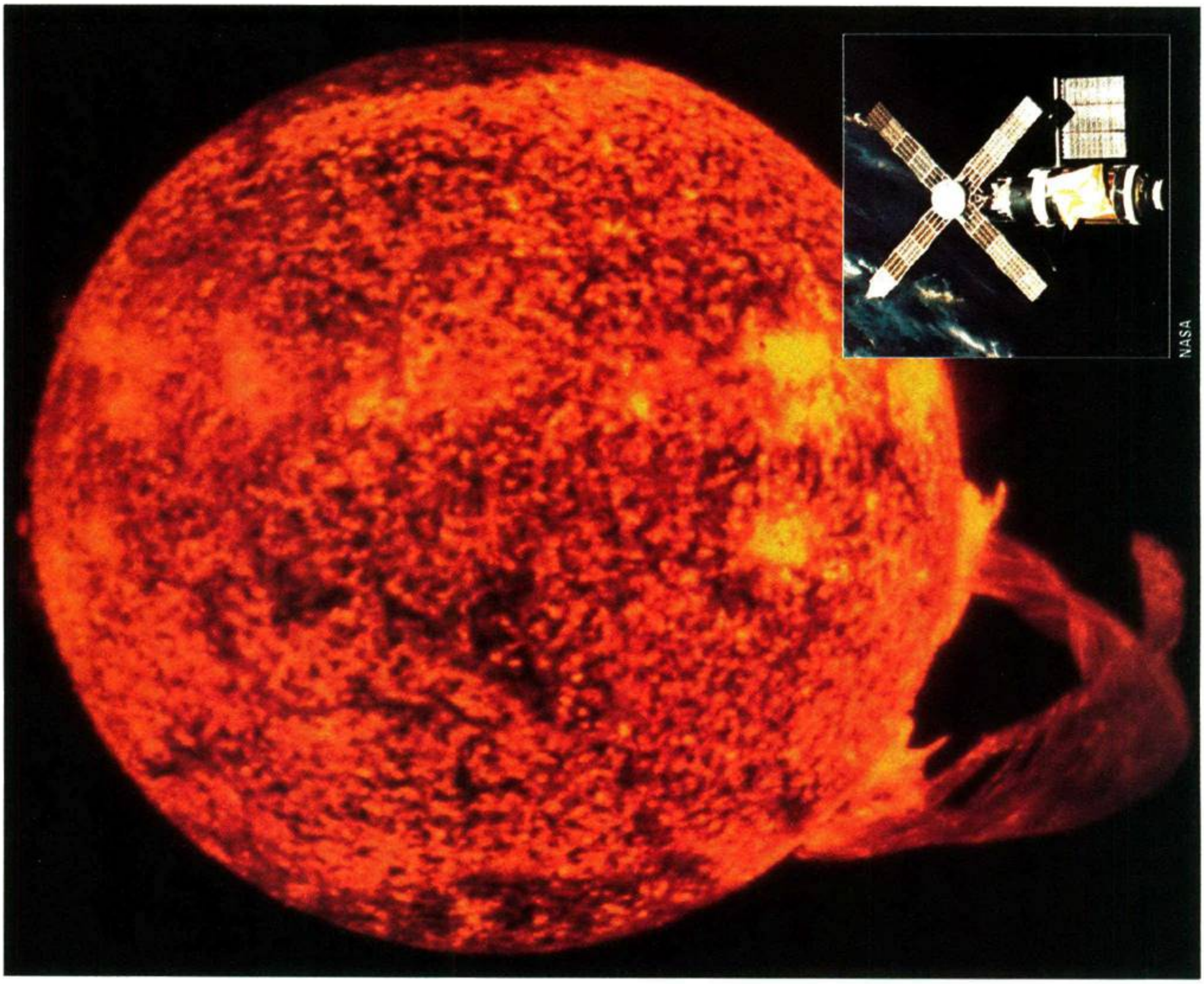
Unlike many things that have changed since I was a boy, hindsight has not — it is still 20/20. From the vantage point we have today, it appears astronomy could have fared better.

If I Had A Hammer

So we have come to this place. It's 1996, the Space Station will be built, and astronomy currently has no apparent role to play or advantage to be gained from this daring, highly capable, and increasingly international venture.


NASA/GSFC

Manned spacecraft *can* conduct important research in astronomy. The Ultraviolet Imaging Telescope, flown on the shuttle's Astro-1 mission, took this image of Omega Centauri.



Naval Research Lab

NASA

America's first space station, the 1973 Skylab mission (inset), monitored the Sun's million-degree corona by observing its X-ray emission. Like most other radiation, X rays are absorbed by Earth's atmosphere.

Let us suppose, for a moment, that the will to change this situation was inside us. What astronomy could be done from the Station to augment the program of work done with unmanned spacecraft? What would make sense?

To begin, astronomers interested in using the facility must recognize that its design is now essentially fixed. As a result, suitable experiments will be those that fit easily within the facility's existing resources. Moreover, they must add to its total sweep of scientific output without jeopardizing returns from the twin pillars that form the Station's scientific base: life and materials sciences.

What kinds of instruments might we put on *this* Space Station, sometime after its research christening in 1999? Amazingly, possibilities abound. Starting with the small and progressing to more ambitious scales, some or all of the following might be possible during the Station's operational life:

- *A simple camera*

The advance in modern astronomical detectors has made it possible for telescopes with apertures as small as 8 inches to be valuable research tools. Indeed, the space shuttle has carried advanced cameras in its cockpit to study aurorae, noctilucent clouds, Comet Halley, and the planets. This kind of equipment, which is small enough to be stored in a mid-sized clothing locker during launch, has flown on more than a dozen shuttle flights since 1983.

Space Station personnel could make valuable use of a similar system to monitor bright comets, planetary meteorology and aurorae, and stellar novae at visible, near-infrared, and ultraviolet wavelengths. Even more useful would be a small spectrometer using the same telescope to gather data on the temperatures, pressures, and compositions of these objects.

- *Gamma-Ray-Burst Detectors*

One of the most intriguing and important problems in astrophysics today is the nature of the mysterious gamma-ray bursts that have been detected in space since the late 1960s (see "Gamma-Ray Bursters: Near or Far?" December 1995). Major advances in the study of gamma-ray bursters have been made with the unmanned Compton Gamma Ray Observatory (CGRO), but still no one knows what causes these powerful and enigmatic events.

As a result, most astronomers who study these events agree that a follow-on to CGRO should include a network of burst detectors scattered among numerous spacecraft in Earth orbit and interplanetary space. Such a network should increase the detection rate of gamma-ray bursts, because it would overcome one of CGRO's inherent limitations — that the nearby Earth blocks about half the sky at any given time.

In addition, a widely distributed, next-generation burst-detection network would help pinpoint the sources of gamma-ray bursts by making possible accurate triangulation on many of the events. Although the bulk of any such network would fly on unmanned spacecraft, a moderate-sized burst detector could fit nicely aboard the Space Station because it requires little power, little telemetry, and virtually no attention from the crew. Gamma-ray-burst detectors are also less sensitive to contamination than many other astronomical instruments. Wouldn't it be fitting if the Station played a role in solving one of astronomy's greatest mysteries, without noticeably impacting its primary research role?

- *Millimeter-Wave Radio Telescopes*

Radio astronomy at millimeter wavelengths is largely the realm of molecule hunters and cosmologists. Much of what makes this science difficult is that even tiny amounts of water vapor in Earth's atmosphere absorb these waves. As a result, millimeter-wave astronomers have resorted to placing their telescopes in far flung places high atop dry mountaintops and in the arid Antarctic wasteland. Even that sometimes isn't good enough. That's the reason one of the first in NASA's new series of Small Explorer spacecraft will be the Submillimeter Wave Astronomy Satellite (SWAS), which beginning this year will undertake a roughly two-year mission to explore both the interstellar medium and the heart of the Milky Way Galaxy.

Like gamma-ray-burst detectors, millimeter-wave instruments require little from their hosts, and can more easily withstand the subtle but necessary pointing jitter that astronauts, life support systems, and docking supply ships will induce on the Station. The SWAS mission will end about the time the first elements of the Space Station are being launched. With a little planning, a successor instrument to SWAS could operate from the Station, thereby avoiding the need for a new spacecraft and dedicated launch.

The limitations on using the Space Station for astronomy are not in ideas, but rather in will.

- *Small Free-Flying Satellites*

One of the best-kept secrets of space astronomy is a highly successful but little-known program called Spartan. For several years now, Spartan spacecraft have been launched aboard the space shuttle, checked out in the payload bay, and then deployed for up to 48 hours. Spartan missions have studied X-ray sources across the Galaxy, searched for black holes, studied the solar corona, and provided vital context measurements for the Ulysses solar polar orbiter. Once a given mission's observing program is complete, the shuttle returns, retrieves Spartan, and brings it to Earth to be outfitted for another mission.

By operating as a free-flying observatory many kilometers from the shuttle, Spartan has overcome one of the dilemmas of doing astronomy using manned spacecraft — optics contamination. The Space Station offers the opportunity to build enhanced Spartans that can operate for weeks, rather than days. After completing a mission, the craft can then return (perhaps under its own power) to the orbiting base to be equipped with a new instrument designed to match its standardized interfaces, take on a fresh load of maneuvering propellant, and be set for another mission.

Skylab captured Comet Kohoutek (right) as it passed near the Sun.

High Altitude Observatory

And the list of potential applications goes on. The limitations are not in ideas, but rather in will.

Back to the Future

The International Space Station can be thought of as a spacecraft platform rich in electrical power, cooling, and telemetry services, with an essentially unparalleled capability for human-tended instrument repair and replacement. Although it is certainly not the platform of choice for many astronomical instruments that would be better served on smaller, cleaner, and more precisely pointed unmanned spacecraft, several astronomical niches can benefit from its presence and capabilities. Because astronomy so intimately sparks the imagination and broadens our intellectual horizons, the inclusion of compatible astronomical instruments on the Station would provide a new research legacy to broaden the program's potential. In this day when all resources for space exploration are under pressure, who is to say we should not consider this possibility anew? □

S. Alan Stern is a planetary astronomer; he directs the Geophysical, Astrophysical, and Planetary Sciences group at the Southwest Research Institute in Boulder, Colorado.

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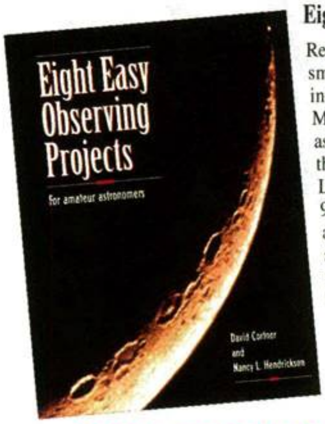
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for amateur astronomers
David Cortner and Nancy L. Hendrickson

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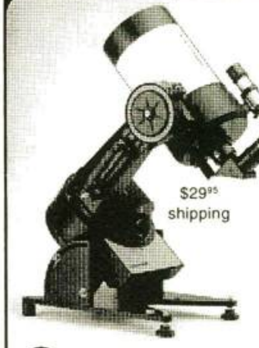
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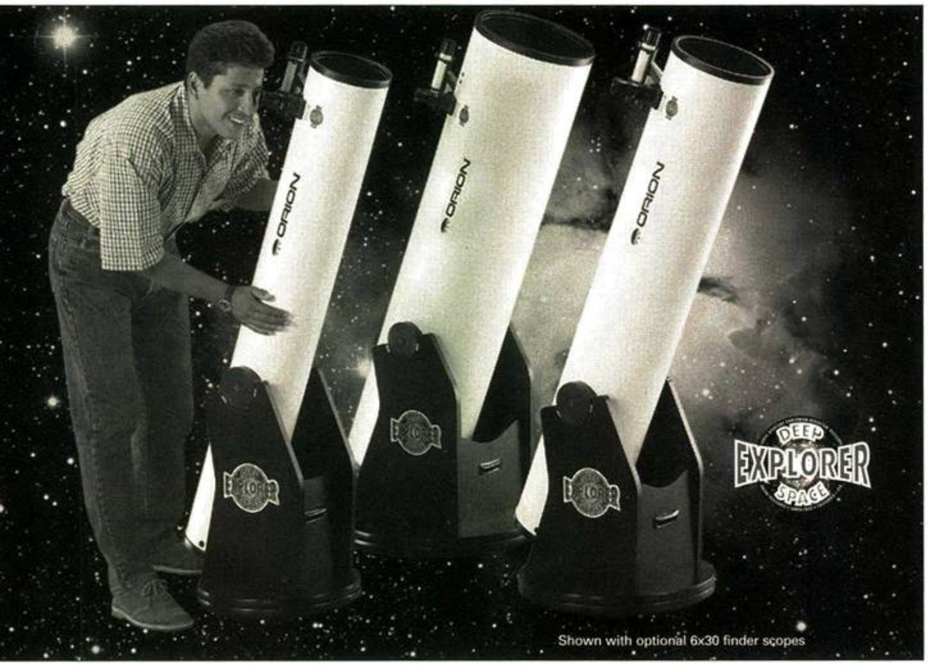

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NEW!

Here's a compact 400mm f/5 scope that's great for both daytime nature viewing and casual stargazing. Features a fully coated 80mm objective lens, rack-and-pinion focuser, 45° erect-image diagonal, TWO 1.25" Kellner eyepieces—25mm (16x) and 10mm (40x)—and a 6x30 finder scope with long-stem bracket. Telescope attaches quickly to any photo-type tripod. Highly portable—take it anywhere!

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6", 8", & 10" Deep Space Explorers

Deep Space Explorer Dobsonians are the "gold standard" in high-performance, low-cost telescopes. Their clean simplicity, rugged durability, and uncompromising optical quality make them ideal for both beginning and intermediate skygazers. They deliver bright, jaw-dropping views of the heavens—you'll be amazed! The wood cabinet Dobsonian mount features zero-backlash teflon bearings for effortless telescope movement, making it easy to manually track objects. Each scope comes equipped with an aluminum low-profile helical focuser and a fully coated 26mm Sirius Plössl 1.25" eyepiece. As an added bonus, we're including FREE a 5x finder scope and mounting bracket—a terrific value!

Now with FREE 5x Finder Scope!

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Shown with optional 8x50 finder scopes

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Comes with high-quality 26mm Plössl eyepiece and NOW with your choice of focuser!

	2" Low Profile	1.25" Rack & Pinion	2" Rack & Pinion	2" Crayford	S&H
10"	#9913 **$799**	#9922 **$819**	#9919 **$859**	#9916 **$899**	(69.00)
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- Durable aluminum optical tubes resist dents and rust.
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- Strong, adjustable aluminum tripod with eyepiece tray
- Slow-motion cables and oversized knob-style motion locks.
- Smooth 1.25" rack-and-pinion focuser.
- Achromatic 6x30 finder scope with two-ring bracket.

SkyView™ 90mm Refractor

This fantastic refractor telescope features a big 90mm (3.5") multi-coated f/11 achromatic objective lens for superb images. Especially suited to planetary, lunar, and stellar observation. It provides spectacular views of star clusters and nebulas. Includes 90° prism diagonal.

#9072 **$599** (28.30)

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Rated the #1 broadband filter by *Sky & Telescope* (7/95): " I Found the Orion SkyGlow to be the most useful."

For slightly to moderately light-polluted areas. .

965" Broadband Filter fits .965" eyepieces. #5661 **$44.95** (2.98)

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2" Broadband Filter fits 2" eyepieces. #5659 **$109** (3.45)

SC Broadband Filter fits rear cell of Meade and Celestron Schmidt-Cassegrain scopes. #5658 **$89.95** (3.45)

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Cuts 87% of the light from the Moon, reducing glare to reveal more detail and help preserve night vision.

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1.25" Advanced Set of 4 #8 Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green. #5570

$49.95 each (2.98)

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CELESTRON

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Save $10!

5mm	*Mfr's List $156*	#8670	~~$89~~ **$79** (3.45)
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24mm	*Mfr's List $176*	#8677	~~$99~~ **$89** (3.45)
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35mm	*Mfr's List $210*	#8679	**$119** (3.67)
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With Superb, High-Performance Ultra™ Multi-Coatings!

Ultrascopic eyepieces yield the highest contrast, greatest light transmission, and best overall image fidelity obtainable. With a superior 5-element design and Ultra™ Multi-Coatings on every surface, they outperform 4-element eyepiece designs. Wide 52° field of view. Removable contoured rubber eyeguard. The 5mm and 3.8mm feature advanced 7-element designs with surprisingly long eye relief. Guaranteed to knock your socks off!

Reduced Up To $20

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Wide-Field 5-Element 1.25"

25mm Ultrascopic	#8564	~~$99~~ **$89** (3.45)
30mm Ultrascopic	#8562	**$119** (3.45)
35mm Ultrascopic	#8560	**$139** (3.45)

High-Power 7-Element Long Eye Relief 1.25"

5mm Ultrascopic	#8574	~~$109~~ **$89** (3.45)
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Sirius™

Quality Plössl 1.25" Eyepieces

Fantastic Fully Coated Eyepieces at an Incredibly Low Price!

You could pay twice the price for other brands of Plössl eyepieces, but why? Sirius Plössls are top-quality, 50° apparent-field (43° 40mm) eyepieces that yield extremely sharp images of impressively high contrast. Ideal for all types of telescopes. The classic 4-element Plössl design is renowned for its fantastic performance. The Sirius Plössl's fully-coated optics are mounted in black-anodized aluminum housings with chrome-plated brass barrels for durability and precision fit. Available in 1.25" barrels only.

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32mm #8728, **40mm** #8730 **$59.95 each** (3.67)

SPECIAL OFFER!

Get a FREE Orion Eyepiece & Accessory Case (#5951) with purchase of four or more Orion Sirius Plössl eyepieces! A $19.95 value!

Dimensions: 11"x7"x3". For description, see eyepiece cases below. Offer expires Dec. 31, 1996.

Orion Explorer II™ Eyepieces

Reliable Performance, Remarkable Value!
Orion's Explorer II models are attractively priced for even limited budgets. Their 3- and 4-element fully coated glass lens configurations provide a pleasing 50° apparent field of view. Threaded for filters.

1.25" Explorer II
25mm #8150, **13mm** #8151, **10mm** #8152, **6mm** #8153 **$34.95 each** (3.45)

.965" Explorer II
25mm #8130, **13mm** #8131, **10mm** #8132, **6mm** #8133 **$29.95 each** (2.98)

PENTAX

Pentax SMC XL-Series

Wide-Angle Premium Eyepeices
With a 5- to 7-element lens configuration that yields a luxurious 65° apparent field, these eyepieces offer truly heavenly views. They feature Pentax's Super-Multi-Coating (SMC) and long 22mm eye relief. One look and you'll be hooked!

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Six-element design delivers tack-sharp images, a wide 68° apparent field, and long eye relief.

15mm 1.25"	*Mfr's List $270*	#8339	**$219** (3.71)
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9mm 1.25"/2"	*Mfr's List $305*	#8331	**$259** (4.11)
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Nagler Type 2

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Double or even triple the power of your eyepieces, maximizing the versatility of your collection. Available in .965", 1.25", and 2" diameters.

Fully Baffled 2x Barlow
Multi-coated, with internal baffling to block transmission of stray light. Premium performance at a remarkable price.

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1.25" 2x Barlow	#8746	**$49.95** (2.98)
2" 2x Barlow	#8724	**$89.95** (3.95)

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Our most versatile barlow. Adjusts to any magnification between 2x and 3x. Fully multi-coated optics. 1.25" barrel. #8748 **$69.95** (3.45)

Shorty™ Barlows
About half the length of our regular barlows for added convenience. Magnifies 2x or 3x when positioned behind or in front of diagonal, respectively, on a refractor or Schmidt-Cassegrain. Works in all scopes, including those in which longer barlows won't work.

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ORION

90° Star Diagonal Prisms

Orion's multi-coated diagonals are ideal for refractors and Schmidt-Cassegrains.

.965" Star Diagonal	#8761	**$29.95** (2.98)
1.25" Star Diagonal	#8763	**$39.95** (2.98)
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For refractors #8770, **for Schmidt-Cassegrain** #8771 **$219** (4.71)

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For refractors #8773, **For Schmidt-Cassegrain** #8772 **$109** (3.45)

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Electronic Finder & Sky Catalog

Let Sky Wizard do the work, while you relax and have fun observing!

- Find any celestial subject in 15 seconds!
- One minute set-up—no polar alignment or levelling.
- For ANY telescope, with or without a motor drive. Even altazimuth or Dobsonian scopes!
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- Built-in electronic sky catalog—find objects by their common catalog name, not their coordinates. Complete with object descriptions.
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Database includes all 110 Messier objects, 28 stars, and the planets. Weighs just 4 oz. #7801 **$179** (4.11)

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Includes two encoders, all required mounting hardware and brackets, connecting cables, and complete illustrated instructions. Installation packages are available for most telescope models. Call for details. **from $166**

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Fujichrome 400, 24 exp.	**$9.98** (1.34)
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Astronomically correct red LED preserves dark adaptation. Shock-proof yellow plastic body is easy to find in the dark. Two AA batteries INCLUDED. #5744 **$11.95** (2.98)

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ORION

Mini Giant 8x56 and 9x63

NEW!

Orion Mini Giant™ 8x56 and 9x63

Get a front-row view of the Comet Hale-Bopp show with a pair of Orion Mini Giants! The Mini Giant 8x56 and 9x63 models will provide grand views, offering wide apertures for excellent light-gathering power, moderate magnification, and a nice wide field of view.

Mini Giant binoculars bridge the gap between traditional 7x50 "night glasses" and larger 70mm and 80mm "giant" models. The big 56mm and 63mm objective lenses collect plenty of light for viewing faint celestial objects. BAK-4 porro prisms and fully multi-coated optics deliver the highest degree of light transmission and contrast.

Orion Mini Giants are easily hand-holdable, but are also threaded to accept an optional tripod mounting bracket. They feature smooth rubber armor for a good grip, a large knurled center focus wheel, right diopter adjustment, and fold-down rubber eyguards. Eye relief is a comfortable 18mm, long enough to see the whole field of view even with eyeglasses or sunglasses on. Includes hard case with shoulder strap, lens caps, and Orion's Deluxe Wide Neck Strap.

8x56 Mini Giant

Lighter and smaller than the 9x63 model. 8x magnification, 5.8° field of view. Weighs 32 oz.

#9361 **$179** (5.19)

9x63 Mini Giant

Slightly higher 9x magnification, 5.0° field of view. Weighs 36 oz.

#9363 **$219** (5.71)

FUJINON
25x150 MT
25x150

70mm Polaris

Fujinon 25x150 Binoculars

The Discoverer of C/1996 B2, Comet Hyakutake

This is the binocular used to discover one of the most spectacular comets of recent history! Even at 11th magnitude, Comet Hyakutake was no match for this binocular's colossal 6-inch objective lenses, patented EBC multi-coatings, and 25x magnification factor. This is the largest binocular in commercial production. Its cast aluminum housings are built to U.S. military specs. The views will knock your socks off! Eye relief, 18.6mm. Field of view, 2.7°. Weighs 41 lbs. We recommend Fujinon's heavy-duty mount and tripod. *(Note: The Telescope & Binocular Center's 30-day money-back return policy does not apply on these binoculars.)*

25x150 Binoculars	#52458	**Call**
Heavy-Duty Mount	#53393	**Call**
Tripod		**Call**

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Awesome Astro Binoculars

For pure star-probing prowess, Fujinon's renowned 10x70 and 16x70 Polaris binoculars can't be beat. Their flat-field optics reduce distortion and astigmatism to virtually undetectable levels. Every surface of the lenses and BAK-4 prisms are coated with up to 13 layers of Fujinon's EBC coatings for greater than 95% light transmission. Tripod adaptable. Individual eyepiece focus. Includes carrying case and lens caps.

10x70 Long eye relief of 23mm, field of view 5.2°, magnification 10x. Weighs 4.8 lbs.
Mfr's List $1080 #52449 **$675** (8.36)

16x70 For extra high power viewing in dark skies. Eye relief 12.4mm, field of view 4.0°, magnification 16x. Weighs 4.8 lbs.
Mfr's List $1150 #52455 **$699** (8.36)

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Orion 50mm Scenix™

High-Quality Binoculars at a Remarkably Reasonable Price

Value-minded observers will appreciate these reliable yet highly affordable field glasses. Every air-to-glass optical surface is antireflection coated, and the objective lenses are even multi-coated for additional light transmission and contrast enhancement. The binocular housing is constructed of sturdy metal, not plastic, and includes a sure-grip rubber covering, a center focusing wheel, plus roll-back rubber eyeguards. Each includes a rugged soft-vinyl carrying case with Velcro closure, lens caps, and a neck strap. Both models have a tripod adapter socket.

7x50 A wonderful model for binocular astronomy as well as for scenic daytime viewing. Bright 7mm exit pupil and a 7.1° field of view. Weighs 28 oz.
#9342 **$96** (4.44)

10x50 Perfect higher-power astronomy binocular that's equally well suited for long-distance terrestrial observing. Uncommonly wide 7° field of view. Weighs 28 ozs.
#9343 **$96** (4.44)

ORION

Orion 50mm Explorer™

High-Performance Ergonomic Design

High-performance, economical binoculars with BAK-4 prisms and multi-coatings. Great for both stargazing and daytime viewing. Rubber body coating for sure grip. Includes case, neck strap, and lens caps.

7x35 A terrific all-purpose binocular. Good under both daylight and twilight conditions. 10mm eye relief, 7.6° field of view. Weighs only 20 oz.
#9302 **$138** (3.95)

8x40 Excellent for birdwatching and lon-distance viewing. These 40mm offer excellent brightness. 6.5° fiewld of view.
#9304 **$138** (3.95)

7x50 Ideal for dark sky astronomy and general purpose terrestrial observation. 6.8°field of view
#9306 **$147** (4.44)

10x50 Higher magnification model with 5mm exit pupil recommended by astronomy experts. Great long distance daytime binocular. 5.3° field of view
#9308 **$147** (4.44)

ORION

Orion 50mm UltraView™

Superb Binoculars Ideal For Eyeglass Wearers

The perfect binocular for eye- and sunglass wearers. Extra-long 23mm eye relief and unique pop-down eyepiece guard. Fully multi-coated optics for high light transmission and maximum contrast. BAK-4 prisms. Close focus 16'. Weighs 32 oz. Includes soft nylon case, eyepiece rain shield, and neck strap.

7x50 High brightness model is best for deep-space astronomy and nighttime surveillance. Works great for all-around daytime viewing. 6.5° field of view.
#9357 **$188** (4.95)

10x50 Highest power model, well suited for astronomical observation and distant terrestrial viewing. 6.5° field of view
#9351 **$188** (4.95)

Also available in 8x42 model.

ORION

Orion 50mm Vista™

Featherlight High Performance Binoculars

Top quality high-performance binoculars. Vista binoculars feature high index BAK-4 prisms and fully multi-coated optics on all air-to-glass surfaces for high fidelity images. Lightweight metal alloy bodies with soft-touch leatherette covering. Long 16-22mm eye relief. Featherlight 28 oz. weight. Include hard carrying case, deluxe strap.

7x50 The brightest Vista has breathtakingly bright images and a 6.0° field of view.
#9355 **$258** (5.19)

10x50 High power model for general purpose astronomy and terrestrial viewing. 5.3° field of view.
#9353 **$258** (5.19)

Also available in 8x42 model.

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Standard Model Great for spotting scopes, cameras, small telescopes. Extends to 59" and folds to 25". Smooth tilt fluid pan head.
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Ultra-Heavy-Duty Model Double strut center braced model is very rigid and suitable for big optical tubes and the largest format cameras. Incredible pan head with separate pan and tilt locks. Height to 73", folds to 39".
#20709 **$349** (5.29)

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8x56, 9x63 Ultima

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8x56	6.1° field, 31 oz.	$349	#9596	**$279**	(5.71)
9x63	5.4° field, 35 oz.	$399	#9542	**$329**	(5.71)

50mm Pro Series (not shown)

A popular choice for those who want a better binocular at a reasonable price. Fully multi-coated optics with BAK-4 prisms insure images of high contrast and clarity. All Pro models are tripod adaptable. They feature a water-resistant, textured covering. A deluxe soft case, neck strap, and lens caps are included.

7x50 Night-Vision Pro The brightest Pro, the 7x50 is an ideal "night glass," but is also useful for daytime and twilight observing. 7.1° field. Bright 7mm exit pupil. Weighs 29 oz.
#9588 **$169** (4.71)

10x50 Long-Distance Pro Ideal for observation at long distances under daytime and dim daylight conditions. 6.5° field, 15mm eye relief. Weighs 30 oz.
#9590 **$169** (4.71)

12x50 Extra High Power Pro The highest-powered Pro, perfect for long-distance viewing under daylight conditions. The 12x magnification requires a steady hand or a tripod. 5.5° field. 10mm eye relief. Weighs 29 oz.
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8-24x50 Zoom Pro Zoom from low to ultra-high power. An incredibly versatile, one-size-sees-all binocular! Field of view 5.0° at 8x. 14mm eye relief. Weighs 31 oz.
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ORION

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10x70 #9501, **14x70** #9494 **$369** (6.97)

80mm Giant Binoculars

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11x80 Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable.
#9502 **$469** (8.05)

16x80 Excellent for astronomy and daytime observation.Tripod recommended.
#9496 **$469** (8.05)

20x80 Highest-power model, perfect for smaller deep-space objects and long-range daytime views. Tripod required.
#9498 **$469** (8.05)

100mm SuperGiants™

Gigantic, nearly 4"-diameter lenses gulp in the light, gathering 56% more than 80mm binoculars. These fine binoculars feature BAK-4 prisms and fully multi-coated optics for the sharpest, brightest possible images. You'll be astounded by the incredible resolution and wealth of detail you'll see. Who said the universe was mostly empty space!

Each model comes with a platform-type tripod mounting plate for added stability. It mounts on any sturdy photographic-type tripod equipped with a standard 1/4"-20 post. Both binocular models weigh 7.5 lbs. and come with a heady-duty, foam-lined metal case with luggage-style handle.

14x100 SuperGiant Features moderate 14x magnification and a 7mm exit pupil, which is ideal for astronomical observation under dark sky conditions. Individual eyepiece focus, rubber eyepuards. Field of view 3.3°.
#9495 **1299** (14.00)

25x100 SuperGiant High-power 25x magnification and a 4mm exit pupil. Center focus, rubber eyeguards. Field of view 2.6°.
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25x100 SuperGiants shown with included adapter plate and optional tripod.

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WIYN Is a Winner

The new 3.5-meter WIYN Telescope on Kitt Peak proves that modest telescopes can still produce breathtaking science.

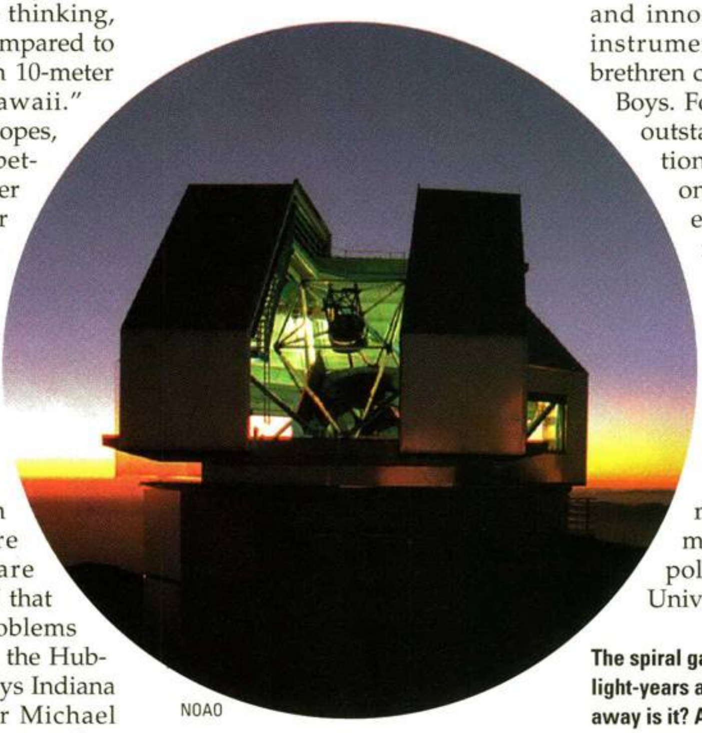
by Robert Naeye

Lying amidst the dozen or so telescopes on the summit of Kitt Peak in southern Arizona is the spanking new WIYN Telescope. WIYN (pronounced "win") boasts a primary mirror 3.5 meters wide. "Big deal," many of you might be thinking, "that's nothing when compared to behemoths like the twin 10-meter Keck Telescopes in Hawaii." When it comes to telescopes, bigger usually means better. Bigger mirrors gather more light, and bigger mirrors generally produce sharper images.

But WIYN and other telescopes in its class are proving that there's still a major role in astronomy for lean, mean, fighting machines. "The image quality of WIYN is high enough that there are some problems that are addressable with WIYN that were thought to be problems you could only do with the Hubble Space Telescope," says Indiana University astronomer Michael Pierce. "That's not to say that WIYN is the same as the Space Telescope, but it does say that you can achieve much higher image quality from the ground than people had thought."

The name WIYN is an acronym for the four institutions that built and operate the telescope: the University of Wisconsin, Indiana University, Yale University, and NOAO (National Optical Astronomy Observatories). The three universities paid for most of WIYN's $14 million construction cost, a relatively low price tag for this day and age. NOAO chips in by paying for most of the operating costs. Each institution is allotted observing time based on its overall contribution: Wisconsin 28%, Indiana and Yale 16% each, and NOAO 40% for national use.

WIYN, which saw first light on May 3, 1994, represents the first partnership between public and private universities, and NOAO (a research facility funded by the federal government through the National Science Foundation). "This consortium is pointing the way to the future, when dwindling budgets and resources will demand similar collaborative efforts," says University of Wisconsin astronomer Jay Gallagher.

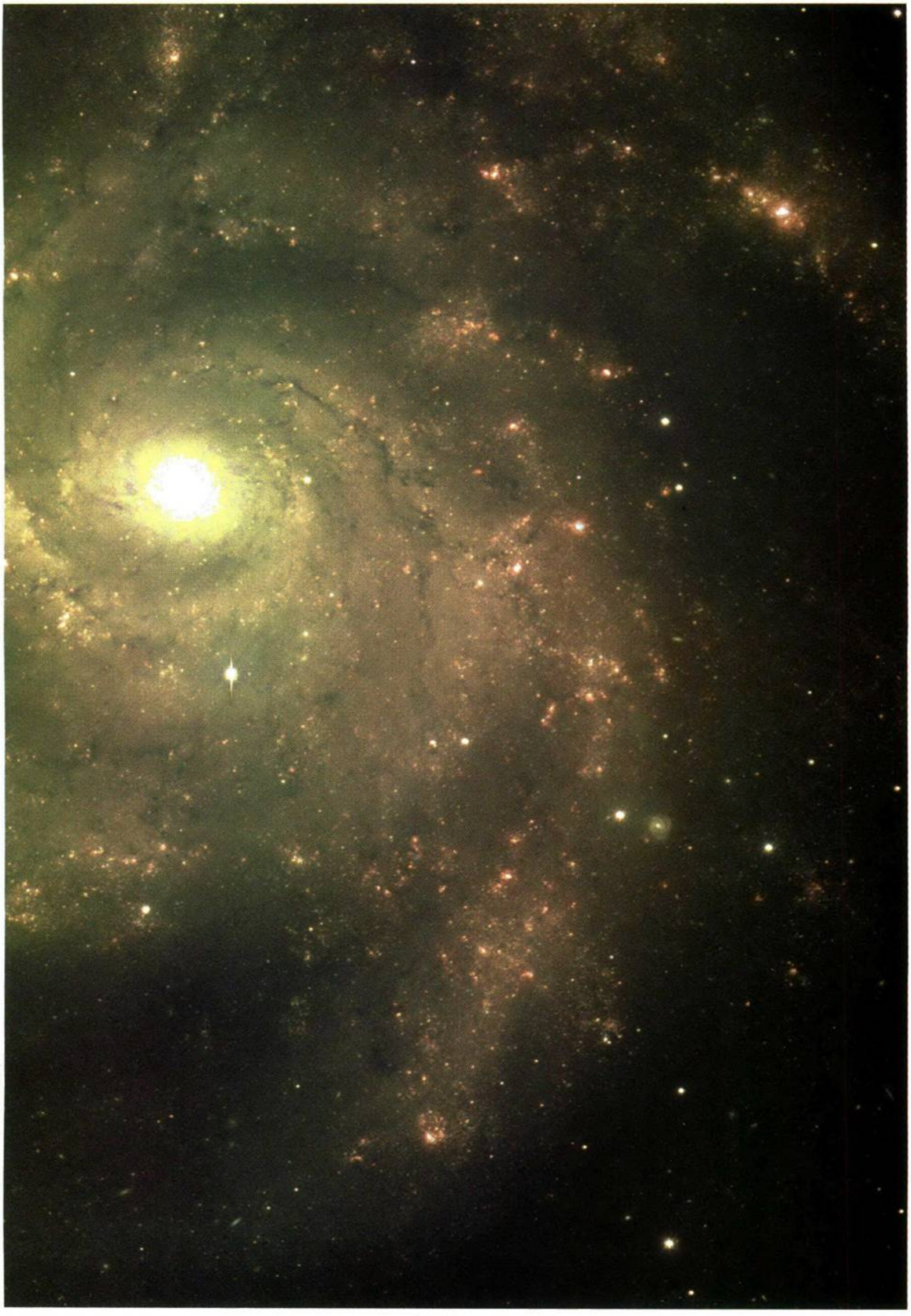


NOAO

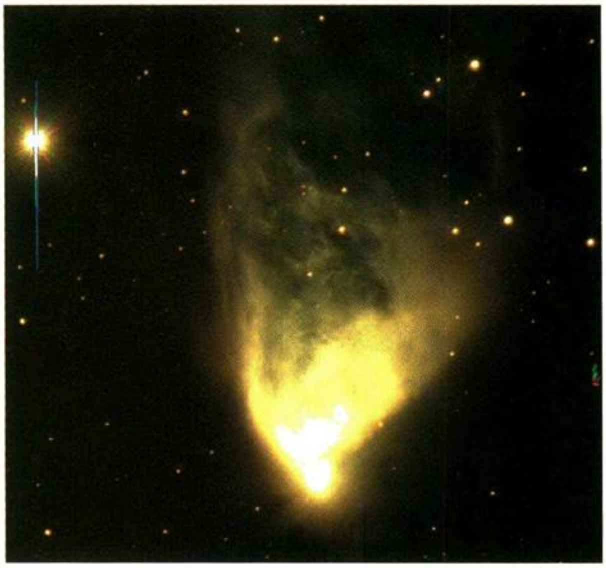
By combining excellent seeing conditions, near-perfect optics, and innovative technology and instrumentation, WIYN and its brethren can compete with the Big Boys. For starters, Kitt Peak has outstanding observing conditions. But WIYN's location on Kitt Peak's southwestern side has the best seeing on the mountain.

WIYN's primary mirror is cast in a honeycomb pattern. This allows the mirror to remain thin (only 40 centimeters thick) and light (2 metric tons), which in turn allows the mirror to be flexible. The mirror was designed and polished by Roger Angel's University of Arizona Mirror

The spiral galaxy M101 is about 24 million light-years away. But *exactly* how far away is it? A team of Indiana University astronomers led by Michael Pierce is trying to find out. They use WIYN images like this one to watch pulsating red supergiant stars in M101's spiral arms brighten and fade over several years. The length of time this takes for each star will tell Pierce's team the star's intrinsic luminosity. Pierce's team will then compare a star's intrinsic luminosity to its apparent brightness to determine the galaxy's distance. Pierce and colleagues will compare this technique to previous methods used to determine distances to faraway galaxies.

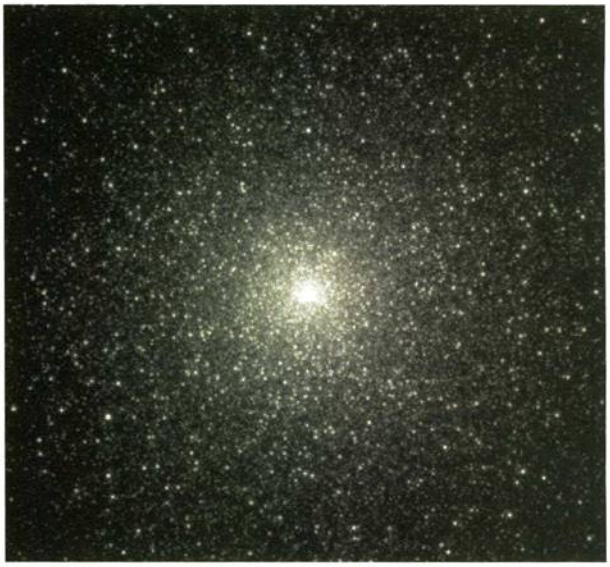


Michael Pierce and John Jurcevic (Indiana Univ.)



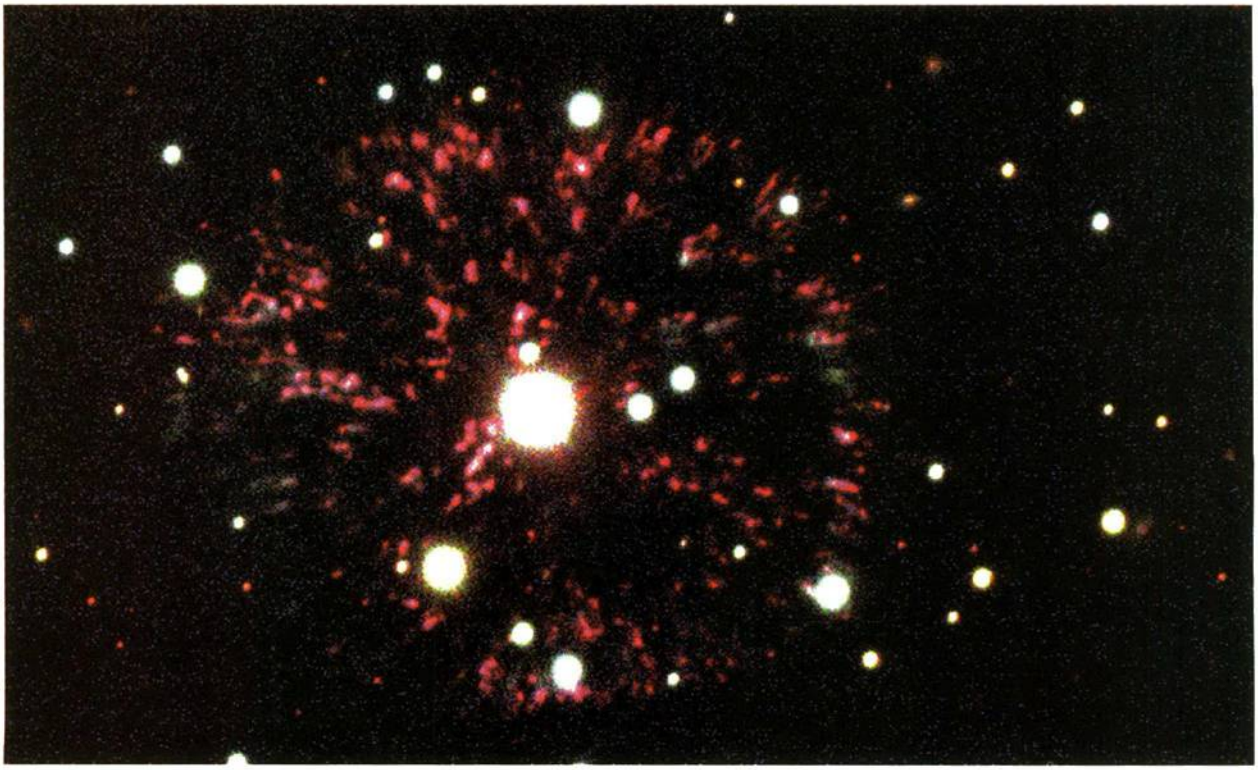
John Jurcevic (Indiana Univ.)

Here we see Hubble's Variable Nebula (NGC 2261) in Monoceros. The nebula's brightness changes by about 3 magnitudes. The variable star responsible for the nebula's shenanigans is R Monocerotis, located at the bottom. The nebula is about 0.7 light-year across and 2,600 light-years away.



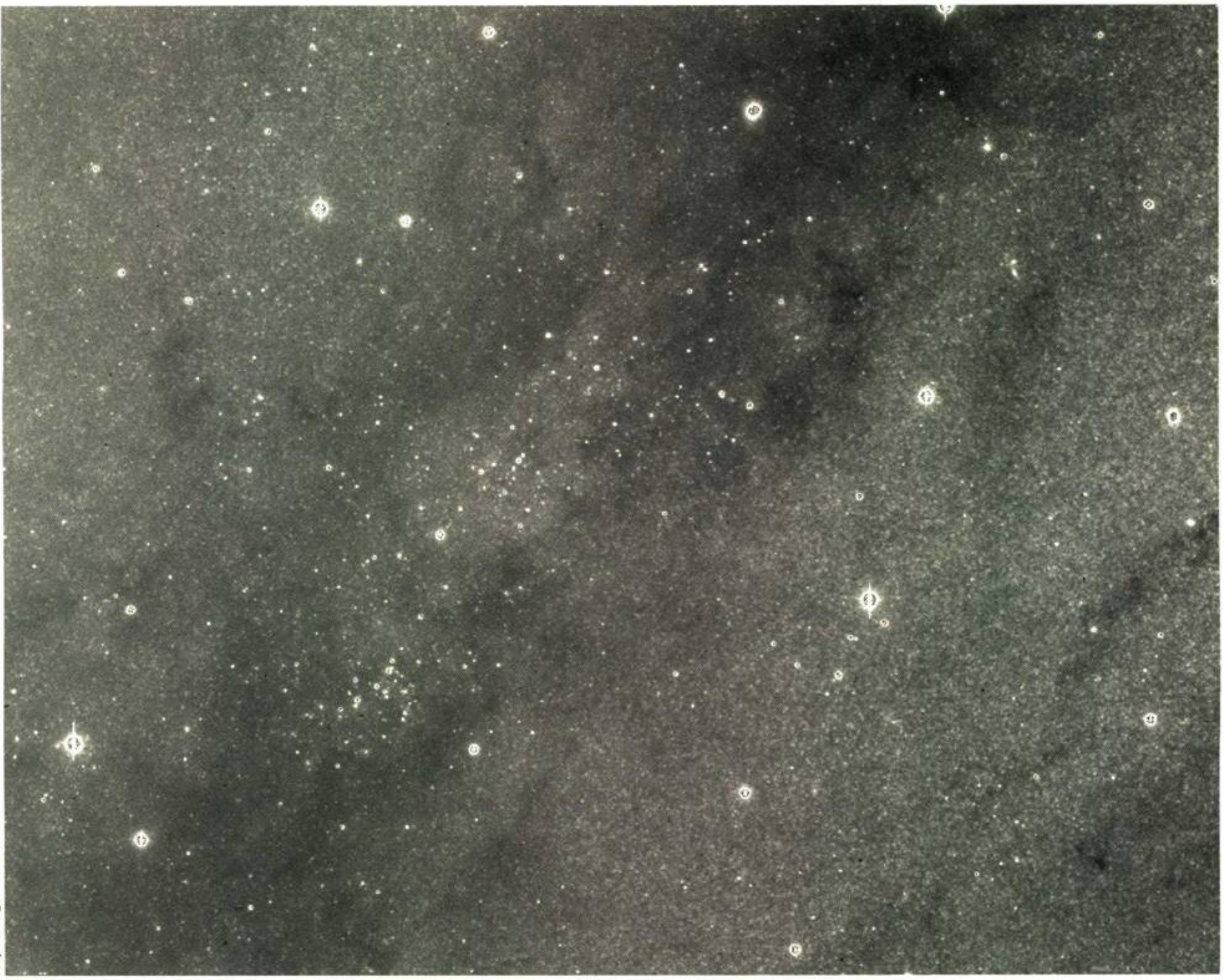
Shawn Slavin (Indiana Univ.)

Indiana University astronomers are studying the evolution of globular clusters such as this one, M15, which is 42,000 light-years away in Pegasus. The scientists record the velocities of hundreds of stars with a spectrograph. The heavier stars sink to the cluster's core, while the lightweights hang out in the halo.



Nigel Sharp, Dave Sawyer, and Alex McDonald (NOAO)

This near true-color photo shows the expanding shell of debris surrounding Nova Persei 1901, 1,500 light-years away in Perseus. WIYN astronomers have informally dubbed this the "Firework Nebula." The nova erupted in 1901, reaching a maximum brightness of magnitude 0.2 (about the same brightness as the brightest stars in the night sky). It's now at magnitude 13.1, 600 times fainter than the faintest naked-eye stars. Astronomers think a cool, bloated star is spilling matter onto a white dwarf star. Every few hundred years, enough matter accumulates on the white dwarf to trigger a catastrophic thermonuclear blast, spewing several dozen Earth's worth of material into space at speeds topping 1,200 kilometers per second. This material rams into dense interstellar gas clouds that surround the nova, breaking the material up into glowing blobs and creating the firework appearance.



Jay Gallagher and Eric Wilcots (Univ. of Wisconsin)

Lab. Angel is renowned in the astronomy community for his innovative mirror designs.

To achieve superior resolution, 66 computer-controlled actuators push and pull on the mirror to compensate for distortions caused by heat, gravity, and mechanical errors. The high-speed computers can refine the position of the actuators 20 times per second, ensuring that the mirror's shape is always at optimum.

WIYN's designers took great care to make sure that the telescope always operates at just the right temperature. As many amateur astronomers know, if a telescope mirror has a different temperature than the surrounding air, turbulence develops that degrades the sharpness of celestial images. "One of the things that surprised me when I got into professional astronomy was to see these enormous telescopes at the wrong temperature most of the time. You could see the air just boiling off the mirror, so the image quality was highly disappointing," recalls Gallagher.

To avoid this pitfall, WIYN has an air conditioning system that heats or cools the mirror's surface temperature so it always stays within 0.2° Celsius of the surrounding air. The building exterior is even coated with aluminum tape, which helps maintain thermal equilibrium.

Finally, WIYN uses an altazimuth mount instead of a larger and more costly equatorial mount. WIYN also has a highly curved mirror, which allows it to have a short focal ratio of f/6.3. This too helped keep the total cost down.

Thanks to these and other innovations, WIYN's resolution is considerably sharper than any other telescope on Kitt Peak. "The goal is to get all there is to get out of

This is an inner region of M31, the great spiral galaxy in Andromeda. The nucleus is toward the lower right. M31 has about the same size and mass as the Milky Way, but the two galaxies make stars in different environments. The Milky Way has many star formation regions scattered throughout the galaxy. But the bulk of M31's star formation is concentrated in a "ring of fire" that surrounds the nucleus. "We'd like to understand why these galaxies are proceeding to make stars in such different ways," says University of Wisconsin astronomer Jay Gallagher. The ring of fire crosses the image on the left side. Lots of stars are forming inside the dark dust lanes.

that site," notes Gallagher. WIYN typically achieves a resolution of 0.8 arcsecond and, when seeing conditions are near-perfect, it has achieved a resolution of 0.4 to 0.5 arcsecond — good enough to see a crater on the Moon only 1 kilometer across. In contrast, most older ground-based telescopes can see craters no smaller than 3 kilometers in diameter.

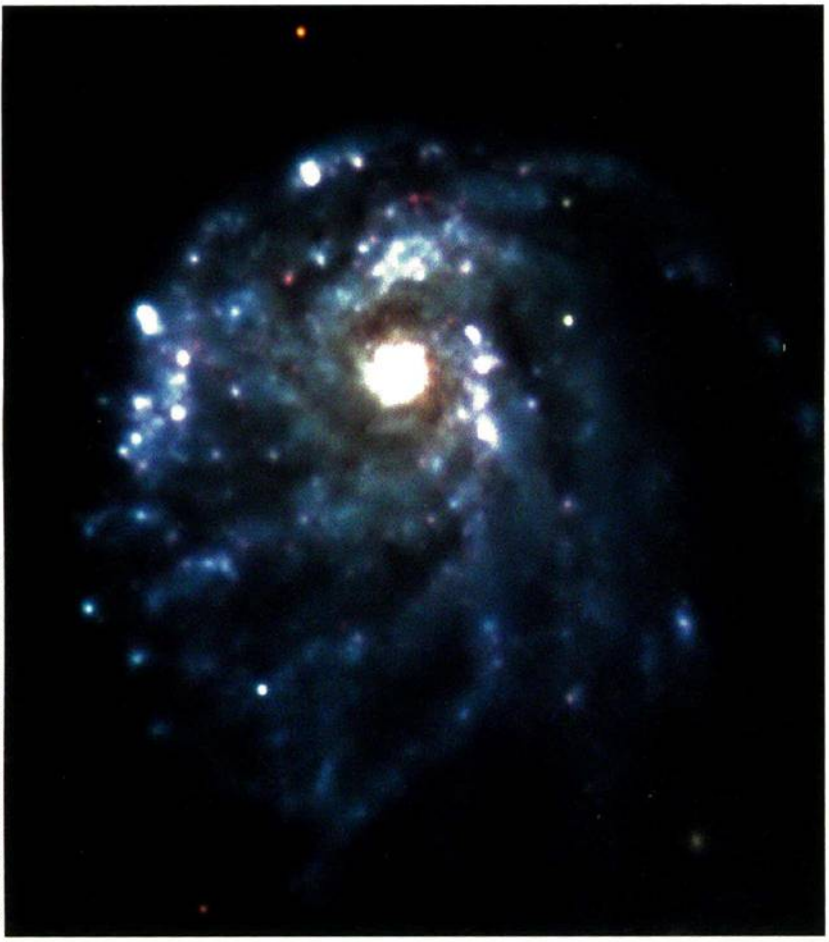
Astronomers have equipped WIYN with three high-tech instruments. The first is a 2,048 by 2,048 pixel CCD camera for taking images. The second is the so-called Hydra spectrograph, whose 100 optical fibers enable it to simultaneously record the spectrum of dozens of objects. The third instrument is a spectro-polarimeter that can measure the spectrum of an object along with the degree of polarization of its light.

WIYN's outstanding resolution, relatively wide field-of-view, and ability to take the spectra of many objects simultaneously make it ideal for studying entire clusters of stars or galaxies. For example, a group at Indiana University led by Haldan Cohn and Phyllis Lugger uses Hydra to observe the motions of hundreds of individual stars within globular clusters like M15, enabling them to understand how the cluster evolves over time.

Another Indiana group, led by Michael Pierce, uses Hydra to measure the internal motions of 50 galaxies within a cluster on a

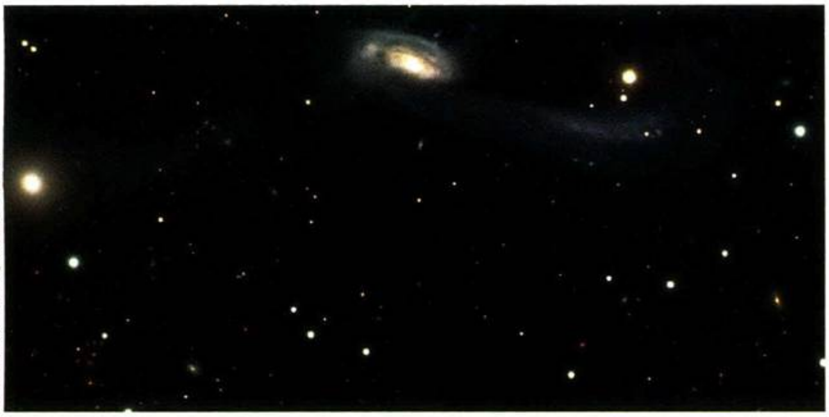
This is the famous Crab Nebula, the tattered remains of an exploded star. The nebula is 7,000 light-years away in Taurus. Chinese astronomers recorded the stellar cataclysm in 1054 A.D. A University of Wisconsin team is watching how the Crab changes over time as the gaseous debris of the destroyed star expands ever outward. The Wisconsin team works in close conjunction with a group of astronomers who peer deep into the heart of the Crab with the Hubble Space Telescope .

Jay Gallagher and Eric Wilcots (Univ. of Wisconsin)



Nigel Sharp, Dave Sawyer, and Alex McDonald (NOAO)

The asymmetrical shape of this spiral galaxy, NGC 2276, is probably due to tidal interactions with the companion elliptical galaxy NGC 2300 (not pictured here). This galaxy is about 160 million light-years away in Camelopardalis.



Chuck Claver and Nigel Sharp (NOAO)

Here we see an elliptical galaxy and a tidally distorted spiral galaxy after a close encounter. "The two galaxies slipped past each other like ships passing in the night," says NOAO astronomer Chuck Claver. Tidal interactions between the two galaxies created the elongated tails. This system, called Arp 102, is about 320 million light-years away. The faint red smudges represent a cluster of galaxies several billion light-years away. The galaxies are so distant that the expanding universe has stretched most of their light into the red part of the spectrum.

single night, something that would take hundreds of hours of telescope time using a conventional spectrograph. A galaxy's internal motion is closely related to its intrinsic luminosity, which in turn allows astronomers to determine the galaxy's distance. Pierce's team is investigating whether they can use this method to determine how fast the expansion of the universe is slowing down.

University of Wisconsin astronomers are using WIYN for a whole host of projects that are far too numerous to mention here. John Hoessel and Mingshenge Han are using WIYN to look at how large-scale structures like galaxy superclusters form. Jay Gallagher and Hoessel are using WIYN to search for variable stars in other galaxies. Astronomers can determine distances to these galaxies based on how long it takes these stars to vary in brightness. Gallagher and his Wisconsin colleague Linda Sparke, along with Rosemary Wyse of Johns Hopkins University, are using WIYN to study the structures of small galaxies in giant clusters. Because small galaxies might be fragile, they are useful probes of a cluster environment. Ted von Hippel and his colleagues are using WIYN to find white dwarf stars in various star clusters. White dwarfs can act as a clock to date the ages of these clusters.

As good as WIYN is right now, it will be even better in the future. NOAO will probably install adaptive optics sometime in the next decade. Adaptive optics compensate for varying atmospheric conditions, improving resolution. NOAO is also perfecting use of WIYN's adjustable optics and the ability for outside astronomers to operate the telescope by remote control. So consider the magnificent images splattered over these pages to be a mere sneak preview of what is to come. □

Robert Naeye (rnaeye@astronomy.com) is an associate editor for ASTRONOMY. *He extends his gratitude to Nigel Sharp at NOAO and Jay Gallagher at the University of Wisconsin for making these beautiful images available.*

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SKY
ALMANAC

Comet Hale-Bopp and giant Jupiter sink into evening twilight under the escort of Mercury. High overhead after midnight, Gemini delivers its perennial Yuletide shower under Moon-free skies.

by Martin Ratcliffe

Highlights
by Rick Shaffer

Date	Event
13	A Yuletide Meteor Shower ......(p. 72)
19	Go Low for Mercury.......(p. 72)
23	Luna Brushes Aldebaran ....(p. 73)

all month:

First Views:
- Orion's Magnificent Nebula ....(p. 69)
- Hale-Bopp's Temporary Farewell ....(p. 70)

Observer's Challenge:
- The Sublime Horsehead ....(p. 71)
- Stalking Interamnia through Perseus ..(p. 73)

Comet Hale-Bopp presents a pre-Christmas treat this month and offers a strong hint of things to come next spring. Early December brings a fine opportunity to view this long-anticipated comet before it passes into the morning sky.

Wandering like an ephemeral nomad among the stars of Ophiuchus and Serpens, **Hale-Bopp** is a fine sight in binoculars and, perhaps, to the city-dweller's naked eye. Moving northeast at less than half a degree per day, the comet crosses the 2 AU mark (twice Earth's average distance from the Sun) from the Sun by mid-month; just 1 AU (150 million km) to go until perihelion next spring.

December opens with Comet Hale-Bopp 31° from the Sun. Even an hour and a half after sunset the comet stands a respectable 10° above the horizon under a dark sky, to the southeast of Gamma (γ) Ophiuchi.

By mid-December however, encroaching moonlight and the comet's descent into twilight make it harder to detect Hale-Bopp's soft glow.

Come late month it slips into the Sun's glare and amateurs across the world begin the wait until its reappearance in the new year's morning sky, likely looking brighter with a growing tail. When is the first time you'll see Hale-Bopp in morning twilight?

Tracking the motions of planets is just as fun and challenging. This month one active player is **Mercury**, the closest planet to the Sun in our solar system.

Mercury's life in the orbital fast lane (its year lasts 116 Earth days) brings the planet to greatest elongation in the western sky after sunset on December 15. The shallow, southerly angle the ecliptic makes with the southwestern horizon on December evenings makes spotting Mercury a challenge for northern observers.

To find it, first locate **Jupiter** shining at magnitude –1.9 low in the southwest half an hour after sunset. Mercury shines

Fred Hafeli

Nothing defines a winter's evening better than Orion the Hunter rising through some slumbering trees. This month, use binoculars or a low-power telescope to discover Orion's star factory, M42. It's the glow (pink in this photo) seen in the Hunter's sword, just below his belt stars.

1996
DECEMBER

1 The Moon is at apogee (404,654 kilometers from Earth), 5:32 a.m. EST

3 Last quarter Moon is at 12:06 a.m. EST
The Moon passes 4° south of Mars, 4 p.m. EST

8 The Moon passes 2° north of Venus, 8 a.m. EST

9 Asteroid Kalliope is at opposition
Asteroid Pallas is in conjunction with the Sun

10 New Moon is at 11:56 a.m. EST

12 The Moon passes 5° north of Jupiter, 6 p.m. EST
The Moon is at perigee (364,237 kilometers from Earth), 11:17 p.m. EST

13 The Moon passes 4° north of Neptune, 2 a.m. EST
Geminid meteor shower peaks (page 68)
The Moon passes 5° north of Uranus, 1 p.m. EST

15 Mercury is at greatest eastern elongation (20°), 2 p.m. EST (page 68)

17 First quarter Moon is at 4:31 a.m. EST
The Moon passes 3° north of Saturn, 3 p.m. EST

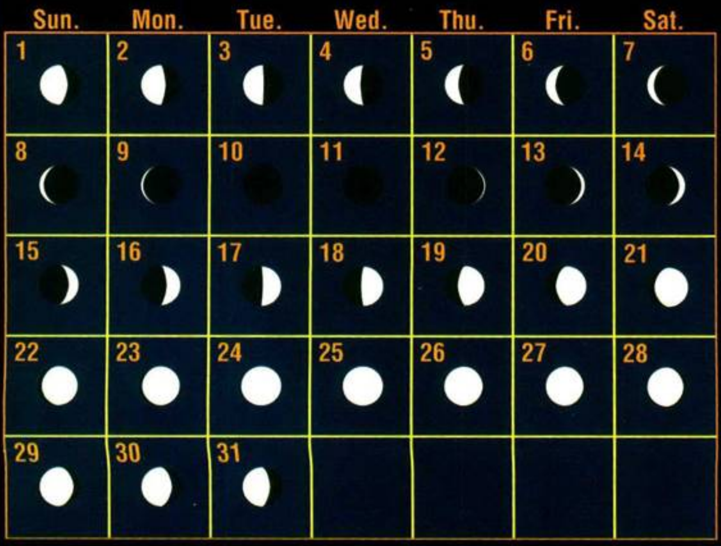
21 Winter solstice is at 9:06 a.m. EST

22 The Moon passes 0.9° north of Aldebaran, 7 p.m. EST (page 69)

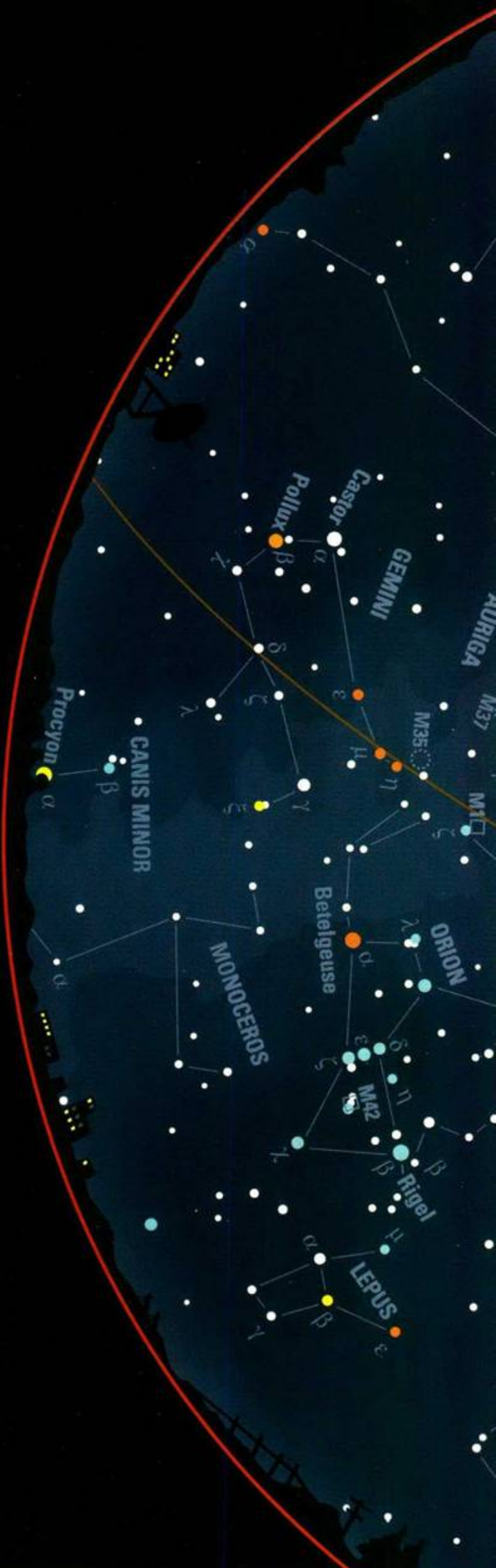
24 Venus passes 6° north of Antares, 2 a.m. EST
Full Moon is at 3:41 p.m. EST

29 The Moon is at apogee (405,522 kilometers from Earth), 12:27 a.m. EST

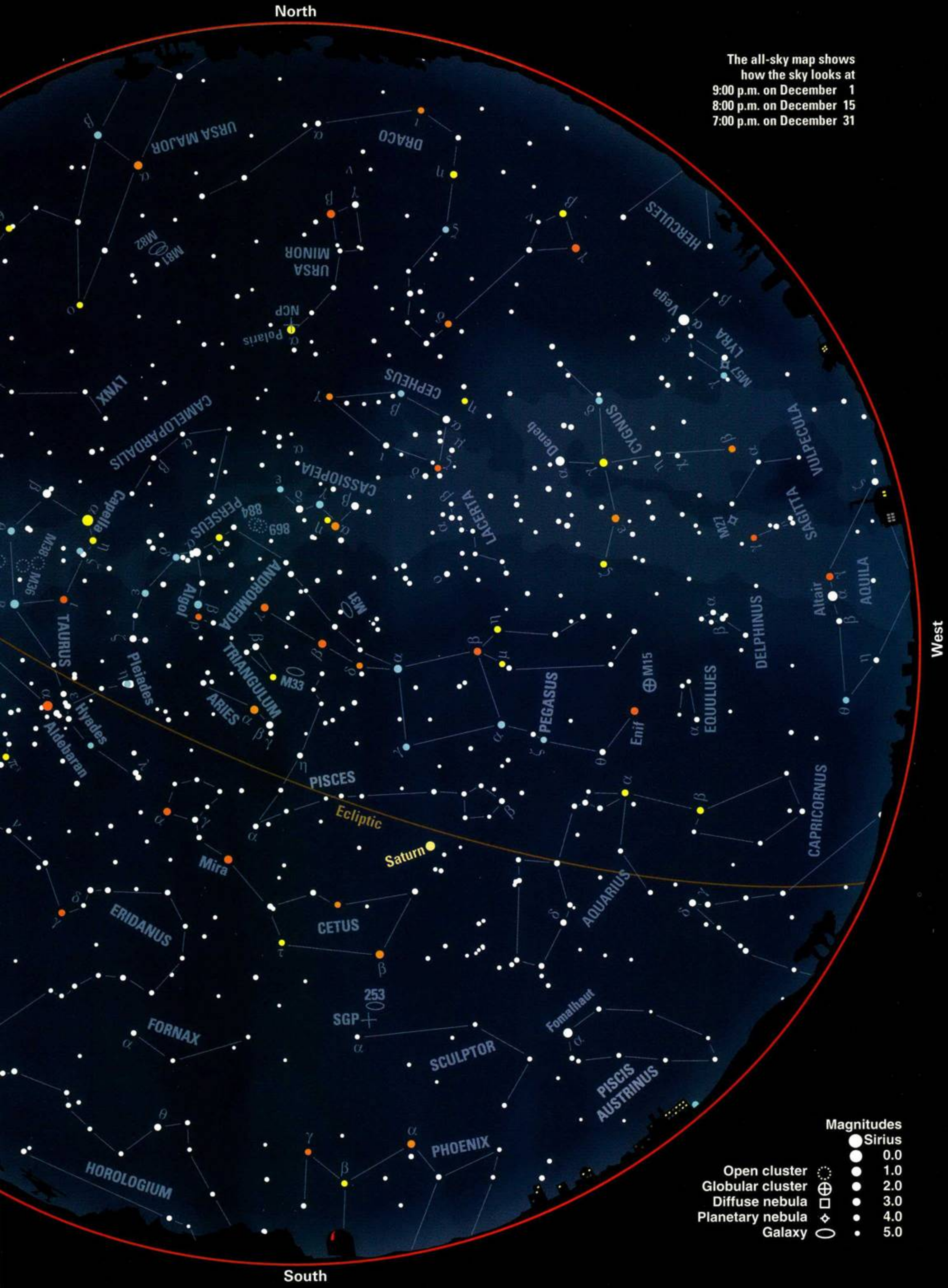
31 The Moon passes 3° south of Mars, 11 p.m. EST



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

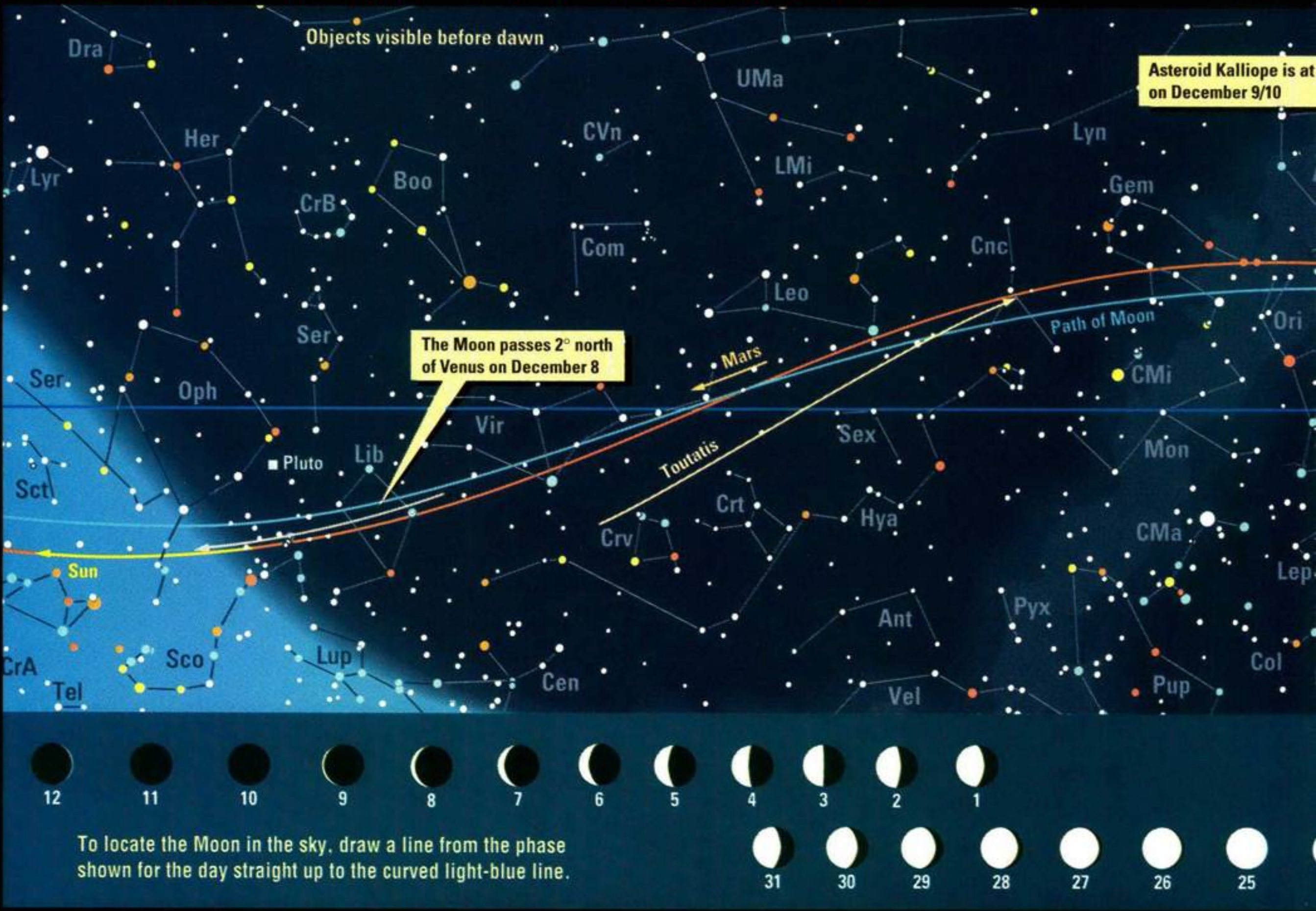


This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars *above your horizon, hold the map overhead* and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


The all-sky map shows
how the sky looks at
9:00 p.m. on December 1
8:00 p.m. on December 15
7:00 p.m. on December 31

North
South
West
URSA MAJOR
DRACO
HERCULES
URSA MINOR
M81
M82
NCP
Polaris
Vega
LYRA
M57
LYNX
CAMELOPARDALIS
CEPHEUS
CYGNUS
Deneb
SAGITTA
VULPECULA
CASSIOPEIA
Capella
PERSEUS
869
884
LACERTA
M27
M38
M36
ANDROMEDA
Algol
M31
AQUILA
Altair
DELPHINUS
TAURUS
Pleiades
TRIANGULUM
M33
M15
EQUULEUS
PEGASUS
Enif
ARIES
Hyades
Aldebaran
PISCES
Ecliptic
CAPRICORNUS
Saturn
Mira
AQUARIUS
ERIDANUS
CETUS
253
SGP
FORNAX
Fomalhaut
SCULPTOR
PISCIS AUSTRINUS
PHOENIX
HOROLOGIUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS

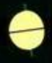

Objects visible before dawn
Dra
UMa
Her
Lyr
CVn
LMi
Lyn
Boo
CrB
Gem
Com
Cnc
Leo
Ser
Ori
Path of Moon
Mars
CMi
Ser
Oph
Vir
Sex
Mon
Toutatis
Pluto
Lib
Sct
Crt
Hya
CMa
Crv
Sun
Lep
Ant
Pyx
Sco
Lup
CrA
Tel
Cen
Vel
Col
Pup
12
11
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27
26
25

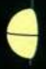
Asteroid Kalliope is at on December 9/10

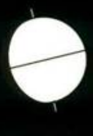
The Moon passes 2° north of Venus on December 8

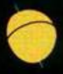
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER
Date	December 1	December 15	December 15	December 15	December 15
Magnitude	–0.5	–0.5	–4.0	0.8	–1.9
Angular Size	5.2"	6.6"	11.4"	7.1"	32.9"
Illumination	89%	64%	90%	90%	100%
Distance (AU) from Earth	1.287	1.024	1.461	1.323	5.991
Distance (AU) from Sun	0.433	0.358	0.722	1.656	5.143
Right Ascension (2000.0)	17h37.1m	19h00.3m	15h41.3m	11h37.3m	19h32.6m
Declination (2000.0)	–25°36'	–24°38'	–18°11'	4°59'	–22°03'

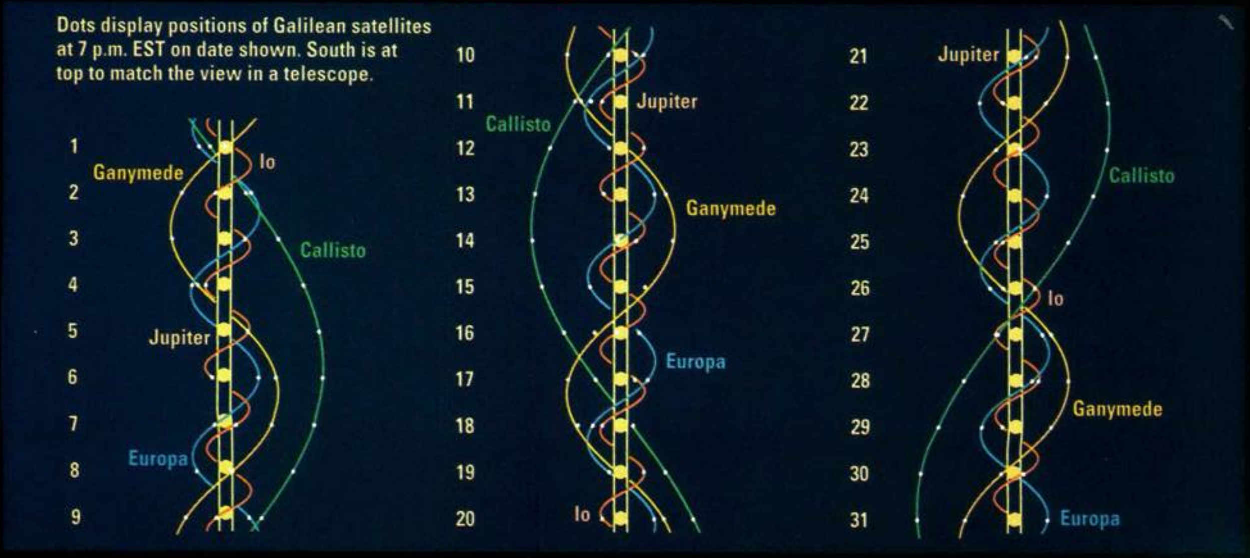




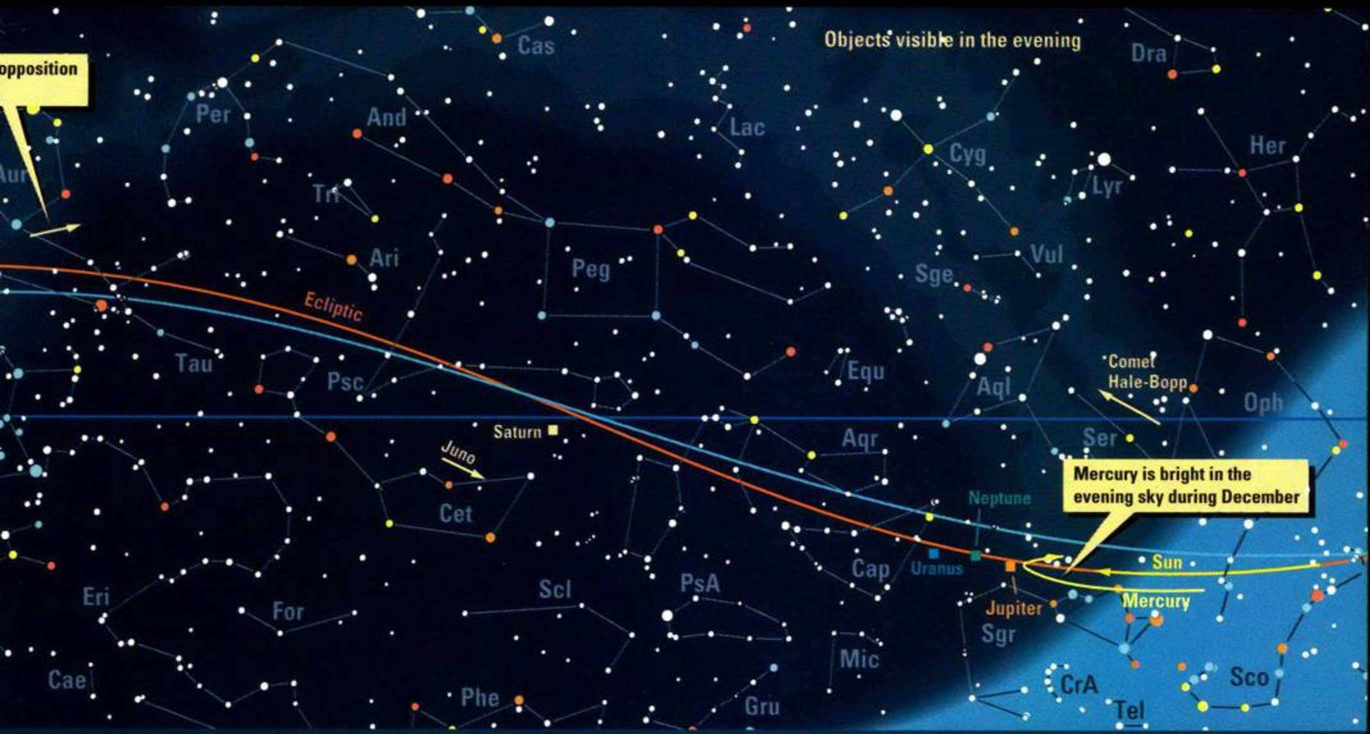




JUPITER'S MOONS

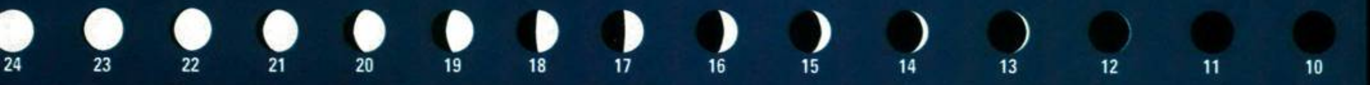


Dots display positions of Galilean satellites at 7 p.m. EST on date shown. South is at top to match the view in a telescope.


Objects visible in the evening
Cas
Dra
Per
And
Lac
Cyg
Her
Aur
Tri
Lyr
Ari
Peg
Vul
Sge
Ecliptic
Tau
Psc
Equ
Aql
Comet Hale-Bopp
Oph
Saturn
Aqr
Ser
Juno
Cet
Neptune
Uranus
Cap
Sun
Eri
For
Scl
PsA
Jupiter
Mercury
Sgr
Mic
Cae
Phe
Gru
CrA
Tel
Sco

opposition

Mercury is bright in the evening sky during December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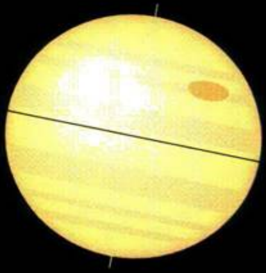
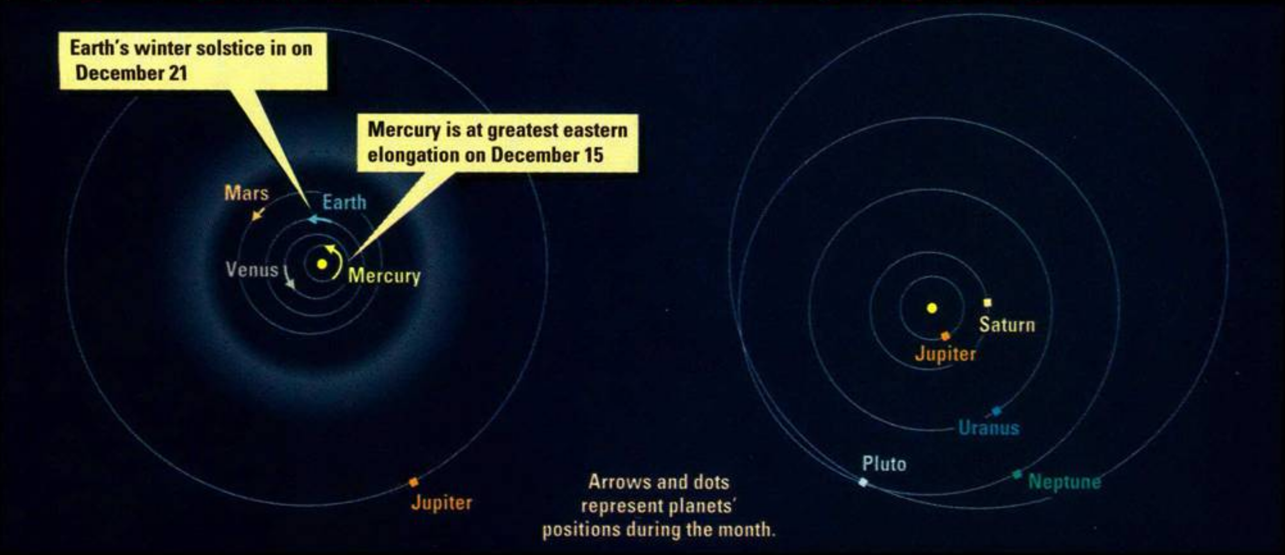


SATURN	URANUS	NEPTUNE	PLUTO
December 15	December 15	December 15	December 15
1.0	5.9	8.0	13.8
17.9"	3.4"	2.2"	0.1"
100%	100%	100%	100%
9.298	20.549	30.978	30.848
9.476	19.795	30.156	29.945
0h06.7m	20h19.4m	19h52.8m	16h16.6m
–1°55'	–20°10'	–20°28'	–8°46'

THE PLANETS IN THEIR ORBITS


Mars
Earth
Venus
Mercury
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Earth's winter solstice in on December 21

Mercury is at greatest eastern elongation on December 15

Arrows and dots represent planets' positions during the month.

west-southwest of the giant planet at magnitude –0.4.

For a greater challenge, try locating nearby **Neptune** and **Uranus** in a telescope before they, like Hale-Bopp, sink into twilight. They lie 3° and 9° east of Jupiter, respectively. Neptune glows at 8th magnitude and Uranus at 6th magnitude. Mercury leads the gas giant trio towards the Sun's glow later in the month. All four planets reappear in the morning sky early next year.

Speaking of things that set in the west, 1996's earliest sunset for people living near latitude 40° north happens on December 7, a whole two weeks before the winter solstice.

This doesn't mean the 7th is the shortest day of the year. It just seems that way because most people are awake at sunset and subliminally measure length of day by noting when the Sun sets. The shortest day is actually on the winter solstice, December 21.

So why should it be this way? The reason is that Earth doesn't orbit the Sun in a perfect circle, but rather in an ellipse. This elliptical orbit causes Earth to move faster around the Sun in January than at other times during the year. This changes the apparent position of the Sun in our sky, which, in turn, affects sunrise and sunset times.

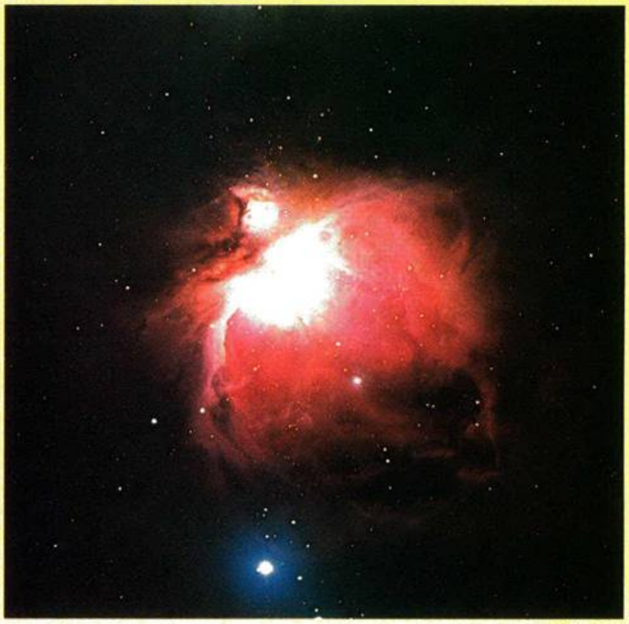
Far from all this activity in the western sky, **Saturn** stands like a sentinel in the south. You'll have no problem spotting this 1st-magnitude beacon, for there are no other bright stars around to detract from its vivid glow.

Through even small scopes Saturn's narrow rings appear as a silver sliver merely 2" thick. Look for their shadow on

First Views:

Orion's Magnificent Nebula

John Shibley



Mike Sisk

Many cultures around our globe have end-of-year holidays. It seems fortunate that the sky provides a holiday gift for our viewing pleasure: the Great Orion Nebula, Messier 42.

In keeping with this good fortune, M42 is located just 5½° south of the celestial equator, so most of Earth's population can see its magnificent light.

The Orion Nebula is part of a vast cloud of gas and dust that takes up the better part of Orion's torso. M42 is the most obvious portion of this complex, glowing as the middle star of the Hunter's sword.

Most observers, even those looking at Orion for the first time, see the middle star as "fuzzy" or "misty" to the naked eye. That in itself is pretty amazing when you consider the nebula lies more than 1,600 light-years away and measures 30 light-years across.

Scattered throughout this huge tract of space is enough material to form 10,000 Suns. The knots and swirls visible in even a small telescope are areas where the less tenuous gas is collapsing into stars. Eventually our distant descendants will see this region as a dense open cluster surrounded by what's left of the glowing gas.

It's not hard to observe the Orion Nebula. With an integrated magnitude of 3, there's a lot of light there. One striking observing method is to point a telescope at low power just west of M42 and allow Earth's rotation to move the nebula slowly into view. This lets you enjoy the many subtleties in its outer reaches before being drawn to the bright, riotous central region.

Embedded in this central region is a tight cluster of stars known as the Trapezium. Four stars are easy to see on even an unsteady night, although at least five more members have been identified.

The dimmest of the most noticeable Trapezium stars is an eclipsing binary. Several of its siblings are pumping out copious amounts of ultraviolet light, which causes oxygen in M42's bubble of gas to fluoresce green for our viewing pleasure.

If the night is especially transparent and your eyes are dark-adapted, don't be surprised if you glimpse some red and purple colors from glowing hydrogen gas. Even my worn out, 50-year-old eyes still see the coloration now and then.

Little kids, whose eyes haven't lost any of their color sensitivity, often look at M42 through my 20-inch telescope and blithely remark about seeing "all those colors."

Only the nebula's beauty suppresses my urge to throttle them. — *Rick Shaffer* the planet's eastern side.

Saturn ends its retrograde loop on December 4, resuming a direct or eastward path among the stars of Pisces.

Far to the east of Pisces lies the majestic constellation Orion, which rises early on December evenings. Its blaze of bright stars dominates the sky so completely that if it were not for Saturn to the west, the autumn sky would already be forgotten.

After Ursa Major's Big Dipper, Orion the Hunter is the sky's best known constellation. Seven striking stars outline the figure of a hunter taken from Greek mythology. His sword holds the Orion Nebula, M42, which never fails to astonish even the veteran deep-sky observer.

Use binoculars to find it 5° below Orion's three bright belt stars: Alnitak (Zeta [ζ] Orionis), Alnilam (Epsilon [ε] Orionis), and Mintaka (Delta [δ] Orionis).

Through a telescope the nebula's billowing gas clouds shimmer in a greenish light. Long-exposure photographs typically record M42 as a red-colored object, but our eyes are not as sensitive to the red glow of hydrogen gas as they are to the nebula's green glow of oxygen gas. See the First Views project box for more information on this fantastic object.

Orion houses other deep sky secrets. One is M78, a small reflection nebula 2½° north-northeast of Zeta Orionis, the leftmost star of Orion's belt. A much bigger challenge is the Horsehead Nebula south of Zeta (see the Observer's Challenge project box).

Orion's mammoth stars Betelgeuse (which marks his left shoulder) and Rigel (his right foot) exemplify the mythological hunter's greatness.

Ruddy Betelgeuse gets its brilliance from sheer size, occupying 160 million times the volume of the Sun. Despite its overwhelming size, the red supergiant star is only 20 times as massive as our Sun. This low-density supergiant star varies irregularly, leading to speculation that Betelgeuse may go supernova. When it does we'll have a relatively safe ringside seat from 500 light-years.

Rigel is also a supergiant star, but appears bluish in contrast to Betelgeuse. This powerhouse shines from 1,400 light years away, and is 50,000 times more luminous than the Sun. Careful viewing through a telescope may reveal a 10th-magnitude companion a mere 10" from the brilliant primary.

Northeast of Orion, Gemini the Twins kid around as they climb to overhead by midnight. Castor and Pollux are the constellation's two principal stars. Castor is actually a sextuplet system, though small telescopes only reveal it as a double separated by 3".

Castor and Pollux belong to a circle of brilliant wintertime stars that includes Procyon, Sirius, Rigel, Aldebaran, and Capella.

This gem-studded winter tiara borders a region of the sky with nearly every known type of astronomical object within easy reach of amateur skywatchers.

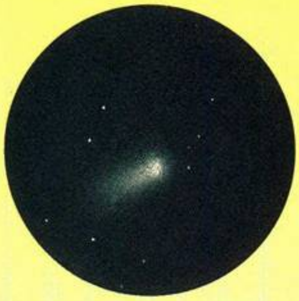
From the star-forming region of the Orion Nebula to the supernova remnant of Taurus the Bull's Crab Nebula, the entire range of star life, double and multiple, variable and multicolored, are here on view. December's long nights allow you to take a journey of discovery among these stellar populations.

You might notice a few meteors flashing through the winter circlet this month. That's because Geminid meteors appear to streak from a point northwest of Castor.

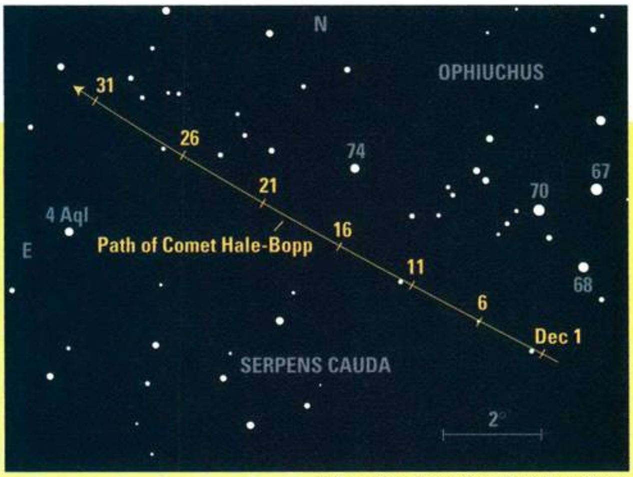
This dependable meteor shower puts on a grand display every year; this month it peaks on December 13.

The Geminids get their name from the host constellation that harbors the shower's radiant. This spot

Hale-Bopp's Temporary Farewell



Comet Hale-Bopp, August 5, 1996
20x60 binoculars, north at top
by Steve Engleman



All illustrations by Astronomy: Elisabeth Rowan

December finds Comet Hale-Bopp finishing a nice run through the evening sky prior to its conjunction with the Sun on January 4, 1997.

For the first half of this month, look for it low in the northwestern sky just as evening twilight ends. First find the bright star Altair; about ⅔ of the way between it and the horizon should be a "fuzzy" star, easily visible in binoculars. Binoculars should also reveal a tail of several degrees.

If the atmosphere's steady, use a telescope to spot any jets of material spewing off the comet's 40 km-wide nucleus. Have paper and pencil ready to make a sketch.

We're now in the home stretch of Hale-Bopp's sprint toward perihelion passage next April 1. For six weeks between December 15 and February 1, Hale-Bopp is exceedingly difficult to view due to its closeness to the Sun. Come mid-February, it'll reappear in the morning sky.

Pay particular attention to Hale-Bopp as it passes close to the Sun in late December and early January. If it becomes the super-comet everybody hopes for, its tail may remain a spectacular evening sight even as the coma moves into the morning sky. — *R. S.*

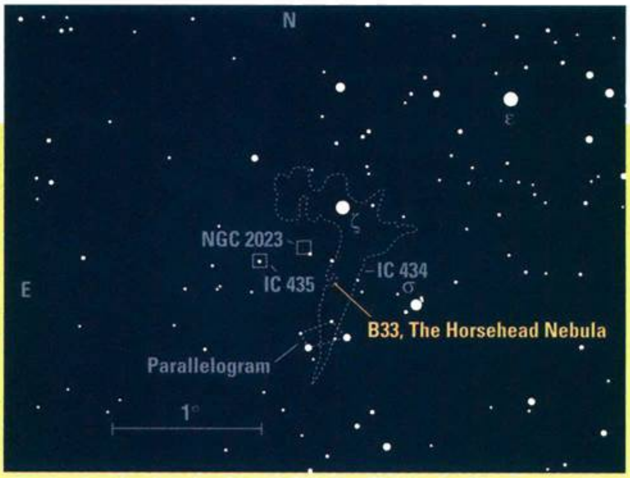
in the night sky marks where all the meteors appear to emanate. Expect 60 to 100 meteors an hour at the height of the shower, which can last a few hours either side of the peak activity.

This year the Geminids should peak at 11 a.m. EST, which favors European and Asian observers. Despite this, North Americans should see significant activity in the predawn hours.

The best time to view any meteor shower is after midnight when the radiant is high in the sky. After midnight is also when the morning side of Earth, the leading edge of our planet in its orbit around the Sun, plows directly into the meteor stream. This increased closing speed also spawns brighter meteors. (See "A Yuletide Meteor Shower" for more about the Geminids.)

Winking Geminids seem appropriate for this time of year. The winter solstice has long been celebrated as a time for lights.

Observer's Challenge: The Sublime Horsehead



Tony and Daphne Hallas

Nebulae in Orion range from the obvious to the sublime. The Orion Nebula is ridiculously wonderful, while the Horsehead Nebula certainly qualifies as sublime.

Also known as Barnard 33, this dark nebula lies between us and an emission nebula, IC 434. Many people assume the Horsehead is just too faint to find visually. Think again. Here's how you can see the elusive Horsehead:

First, ensure that your telescope's optics are really clean. Be sure to also clean your lowest power eyepiece plus any light pollution rejection filters you might use.

Next, seek out as dark an observing site as possible. Getting really far away from city lights is a requirement for observing deep-sky objects at the limit of visibility.

Also, because the Horsehead lies in the southern part of the sky, make sure no sources of light lie south of your observing site.

Picking the right night to observe the Horsehead is also important. Select the second clear night after a cold front goes through, after the winds die down and seeing is much steadier. Such nights also have very little water vapor in the air to scatter light and reduce contrast.

Finally, get your eyes thoroughly dark-adapted before starting your search. This means that you must not look at anything bright for about an hour — not even a bright star like Sirius!

The famous 19th-century astronomer John Herschel covered his eyes with a black cloth for as long as 30 minutes before attempting to see especially faint objects. You might try that. Present-day, die-hard observers hang a black cloth over their heads to block out all light except that coming from the eyepiece.

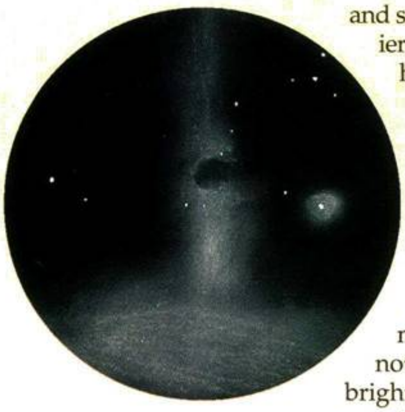
To detect the Horsehead, you'll need maximum contrast in the telescope's field of view. This means using an eyepiece that yields the same-sized exit pupil as the pupil of your dark-adapted eye.

A light pollution reduction filter also increases contrast. A company called Lumicon even sells an "H-Beta" specifically designed for the Horsehead.

I first detected the Horsehead in 1981 with a 19-inch f/4 Newtonian operating at 70-power. I flashed a filter between my eye and the eyepiece to first find the Horsehead, and then removed it to barely glimpse it with eye and eyepiece alone.

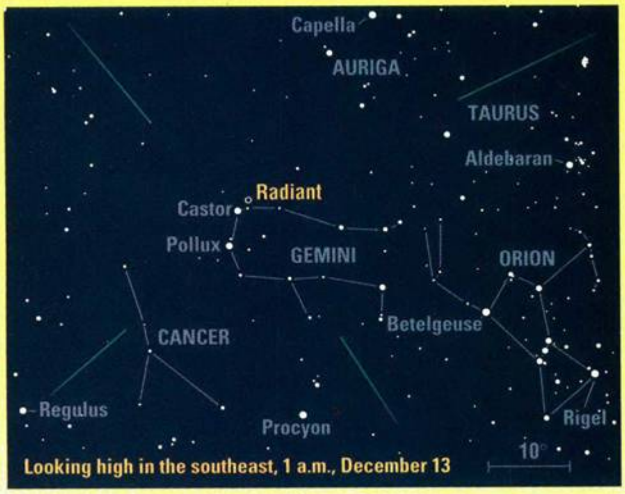
As I tried to find the Horsehead that evening, my field of view accidentally glanced nearby 2nd-magnitude Zeta (ζ) Orionis, which cost me another 30 minutes to allow my eye to re-dark-adapt. Avoid this by approaching the Horsehead from the south, taking care to stop short of Zeta.

A handy parallelogram-shaped asterism proves particularly helpful in finding the Horsehead. Not only is it only slightly larger than the nebula, but it's also a quarter degree south and a little east of B33. Look for a bar-shaped break in the incredibly faint nebula running past it. — *R. S.*



The Horsehead Nebula, B33
13.1-inch f/4.5, 60x, south at top
by Lee Cain

A Yuletide Meteor Shower



Looking high in the southeast, 1 a.m., December 13

Steve Edberg

Along with the Orion Nebula, December presents us with another gift: the Geminid meteor shower. This year's shower is especially favorable because New Moon falls on the 10th, two days before the shower peaks on the night of December 12/13.

What's more, the Geminids are active between the 6th and the 19th. Observe Hale-Bopp just after sunset, swing over to the eastern horizon, and then begin observing meteors.

Because this is a winter shower, keeping yourself toasty is important. A sleeping bag and lawn-chair combination will keep you warm, along with a thermos of soup or coffee.

Don't forget a good, warm hat, as well as a pair of wide-angle binoculars with which to view the smoke trails that 1 in 25 Geminids leaves behind.

Concentrate your search on an area of sky about 45° ahead of the point from which the meteors appear to radiate. Early in the evening this is northeast at an altitude of 45°, where Gemini hugs the horizon. This area climbs to the zenith as night progresses.

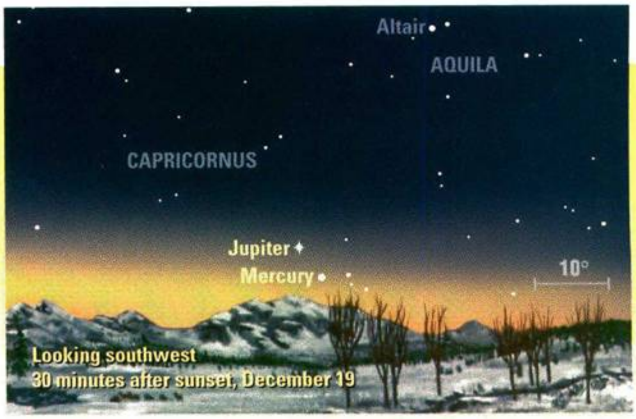
Astronomers believe that most meteor showers occur when Earth's orbit crosses the orbit of a comet. Meteors are grains of dust released from a comet as it approaches the Sun. Often, the parent comet wears away with time to leave just a stream of dust.

The Geminid meteor shower, however, is different. An asteroid, 3200 Phaeton, lies in the same orbit as the Geminids. This discovery, made by a satellite in the 1980s, suggests that some comets may have solid cores lurking beneath a layer of dirty snow.

In the Geminid parent comet's case, when all the snow melted, an asteroid was left, plus many, many meteoroids all rolling along in the same orbit.

When Earth runs into these meteoroids December 13, we can expect to see as many as 60 to 100 Geminids per hour. The meteors should also be bright, averaging magnitude 2½. — *R. S.*

Go Low for Mercury



Looking southwest 30 minutes after sunset, December 19

December isn't an ideal time to observe Mercury in the evening sky, so finding the elusive planet just after midmonth isn't going to be easy. It would be more of a challenge if not for bright, nearby Jupiter.

Start looking with binoculars for Mercury low in the southwest about 30 minutes after sunset, where Jupiter shines at magnitude –1.9 about 10° above the horizon.

On December 19, Mercury should be just 4½° below Jupiter, twinkling at magnitude – 0.1.

You'll see little detail on Jupiter and only Mercury's half-lit phase. Note the tiny planet's extremely yellow color, a combination of its intrinsic color and the effects of Earth's atmosphere.

Bear in mind that 4,900-km-wide Mercury is close in size to Jupiter's four large Galilean satellites. One Jovian moon, Ganymede, is actually bigger.

Only its location in the solar system allows Mercury to be classified as a planet, where the Galilean satellites are mere moons of Jupiter. — *R. S.*

At this, the darkest time of the year, festivals were held to lift spirits and recognize the fact that spring was not far away.

We still celebrate this time with thousands of colored lights throughout neighborhoods. This year a Full Moon on December 24, Christmas Eve, adds to the illumination. The December Full Moon is called the Moon before Yule, or Long Night Moon.

Two nights before, on December 22, Luna passes very close to ruddy Aldebaran in Taurus, actually occulting it for residents of the northern Great Lakes, Canada, Greenland, Iceland, and parts of Norway and Finland. The coming year will provide more of these occultations, some visible from more southerly locales.

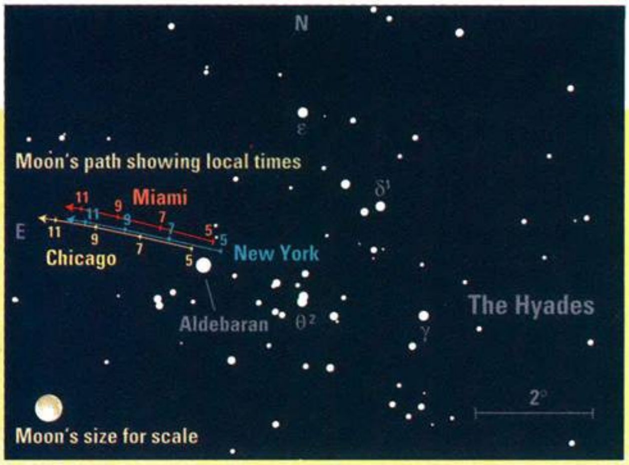
Another ruddy object, **Mars**, shines in the post-midnight hour from southeastern Leo. It leaves the lion by midmonth to cross into Virgo. At the same time the Red Planet brightens to a respectable magnitude 0.6. Look for it to greet the morning light of December 4 with a waning crescent Moon.

Venus doesn't rise until well into the glow of dawn, yet its brilliant magnitude –4.0 makes it hard to miss. The Moon glides a couple of degrees past Venus on the North American morning of December 8.

On December 24 the bright planet lies less than 6° north of Antares, the brightest star in Scorpius the Scorpion. Look low in the southeast as the sky brightens with approaching daybreak. □

Martin Ratcliffe directs the Henry Buhl, Jr. Planetarium in Pittsburgh, Pennsylvania. Rick Shaffer is a science writer living in Cornville, Arizona.

Luna Brushes Aldebaran



Observers in eastern Canada and the northern Great Lakes states see the Moon cover the ruddy eye-star Aldebaran just after sunset on the evening of December 22.

If you live north of a line between Chicago and Quebec City, you'll see the occultation. People who live on the line see the star graze the Moon's south pole.

Those south of the line see the Moon pass just north of Aldebaran; west of Chicago, Aldebaran is lost in evening twilight.

People everywhere should enjoy seeing the Moon saunter away from the V-shaped Hyades cluster that forms the head of Taurus.

If you feel like timing the occultation, contact the International Occultation Timing Association (IOTA) by e-mail at 570-0611@mcimail.com.

They'll be happy to provide you with all the info needed to participate in documenting this and other upcoming events. Data collected by IOTA lets astronomers better refine the Moon's motion around Earth.

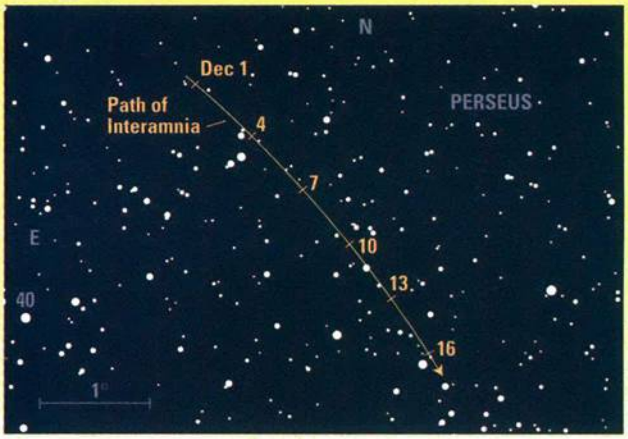
Otherwise, just watch it through a pair of binoculars or a small telescope. Invite as many neighborhood kids as you can, as this is a good opportunity for them to actually comprehend the Moon's motion through the sky.

The conjunction also offers a good photo opportunity. A medium telephoto lens (135, 200, or 350mm) should capture an ample field of view around the Moon.

With the camera mounted on a tripod and the lens wide open, shoot on ISO 400 film with exposures that vary between 1 and 20 seconds. — *R. S.*

Stalking Interamnia through Perseus

This column's been following asteroid 704 Interamnia since it reached opposition last month. This month it's still easily glimpsed among the stars of Perseus. The finder chart shows the path of this 10th-magnitude object as it moves more than 3° through the sky during December.



Although Interamnia is the sixth largest asteroid known, 334 km in diameter, it was only the 704th asteroid discovered. Why? Interamnia may be big, but it's also very dark. Only 6% of the sunlight that strikes it gets bounced back into space.

It's not surprising, then, that it wasn't found until 1910 by an Italian astronomer, who named his find after an ancient Italian city.

Those of you with CCD cameras might try taking photometric measurements of Interamnia to detect its 8.7-hour "day." Can you catch a variation in the asteroid's brightness over that period? — *R. S.*

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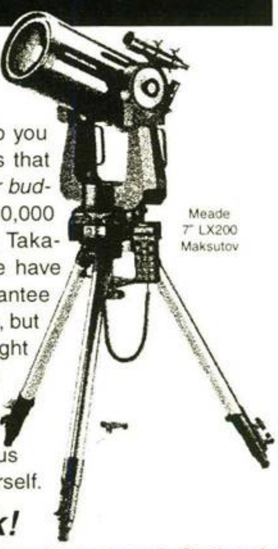

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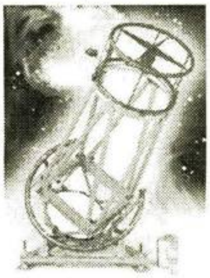

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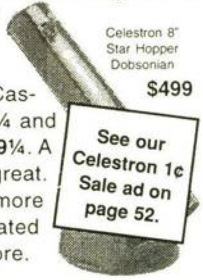

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- The **Star Hopper**™ **6"** and **8"** primary mirrors are housed in 8" and 10" ID tubes respectfully. The oversized flat black anti-reflective painted tubes reduce light scatter and tube currents. These features increase image contrast and improve "seeing" when viewing planets and the Moon.
- The **V-Spectrum LTM Optical System** features a unique molded **Pyrex** mirror, **multi-coated** for increased reflectivity, that provides superior optical and thermal qualities and it is mounted on the **Pinnacle** mirror cell.
- The **V-Spectrum LTM (Low Thermal Mass)** mirror is manufactured and figured to reach the optimal marriage of weight to optical surface resulting in a mirror with 40% less mass than traditional mirrors. Reducing the mass lowers the "cool down" period required to bring the mirror to ambient temperature and leaves more time for observing. An optional fan can be placed behind the **Pinnacle** mirror cell to create a laminar flow of air over the **V-Spectrum LTM** primary mirror to optimize the mirror for planetary and high power observations..
- Our unique and heavy duty, single vane secondary mirror bracket creates minimal obstruction allowing more light to reach the primary.
- Our unique mount features a 10° angled rocker box which increases stability.
- Ultra smooth motion in both axes for easy finding and observing of objects.
- Included standard are a smooth operating 1¼" Rack and Pinion Focuser, a handy Collimation Tool, 25mm SMA (52°) Eyepiece – 1¼" (49x).
- Numerous accessories are available including various pointing aids — from a traditional 6x30 Finderscope, to a state-of-the-art zero power red dot pointing device — the **Star Pointer**, to the Astro Master® models to computerize your telescope.
- Manufactured at Celestron's factory in the U.S.A.
- All of the above features and yet an economical price.

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C4.5 Its 900mm focal length (f/7.9) optical system is housed in an aluminum tube. The mirrors (primary and secondary) have multi-coatings for improved contrast and resolution. The premium optics are manufactured in Japan to rigid **Celestron** specifications.

The **C4.5** uses the Polaris mount which is a very rigid German equatorial type. The very rigid wood tripod is fixed in height for added stability and is supplied with an accessory tray. A quote from *Astronomy Magazine*, "the **C4.5** stands out from the pack by having by far the best mount. Its Polaris mount is wonderful. Solid. Smooth. And with a damping time of two seconds. It was a joy using this telescope." "This is a first-rate telescope that outclasses the competition in the popular 4½" class of Newtonians." Further they said, "the C4.5 star images were classic textbook Airy disks".

Standard accessories include a 26mm multi-coated Plössl Eyepiece – 1¼" (35x), high quality 6x30 Finderscope and a 1¼" Focuser.

Firstscope 114 Its 910mm focal length (f/8) optical system is housed in an aluminum tube. This high quality yet economical telescope is made in a modern, high quality telescope factory in China to **Celestron's** specifications.

The equatorial mount is stable and includes setting circles in both axes as well as slow-motion cables in both axes for easy tracking. The wood tripod is adjustable in height and includes an accessory tray.

Standard accessories include a 5x24 Finderscope, 1¼" Focuser (with a .96" adapter), 20mm H–.96" Eyepiece (46x), 4mm SR–.96" Eyepiece (228x), 2x Barlow Lens –.96"

A **Firstscope 114 Deluxe** model is available which replaces all .96" accessories with two high quality 1¼" eyepieces – 25mm SMA (36x) and 10mm SMA (91x). The 1¼" accessories give you sharper views, a wider field of view and better eye relief.

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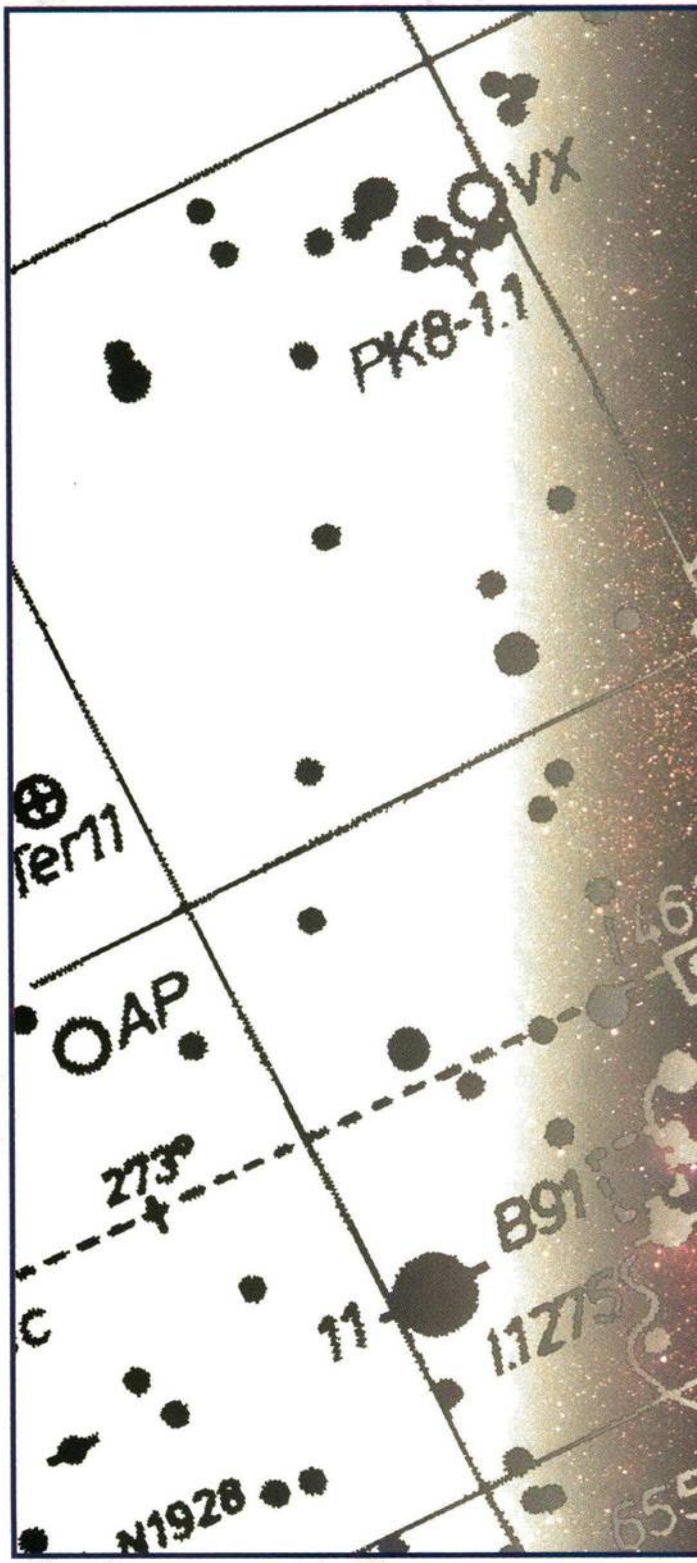
Star Maps Are a Gazer's Best Friend

Pack the right road atlas before embarking on your trip into the cosmos.

by Mark Coco



Geographers say the best way to learn a country's location is to consult a globe. But that same globe fails miserably at helping locate the corner of Michigan and East Adams in downtown Chicago. Such is the nature of a globe to show Chicago as a tiny dot; the depth of scale and detail just isn't there, nor was it intended to be. Other, more detailed maps reveal the Windy City's network of streets, avenues, and boulevards.

In a similar way, star atlases offer distinct features that make them useful for certain tasks. An atlas that works well for learning the constellations may fail to show the location of Stephan's Quintet, a faint group of galaxies in Pegasus. Large-scale maps show only brighter stars to avoid crowding, while small-scale atlases reveal a greater number of faint stars and deep-sky objects.

In this way, each atlas varies by two factors: the scale by which it covers the sky and how faint it goes in stellar magnitude. With this in mind, let's consider which atlas works best for the type of observing you want to accomplish.

Look Far and Wide

If you're just starting out in astronomy, select an atlas that covers large tracts of the sky. Such a wide scale is indispensable when it comes to recognizing and learning the constellations. Most constellations show up on one page, making it a breeze to identify the obvious stars that make up the star patterns. A large-scale atlas also shows some of the brighter deep-sky *objects*, some of which are the famous Messier objects.

One such large-scale atlas comes bound into the center of this magazine each month. ASTRONOMY's Star Dome shuffles constellations along from month to month as seasons pass. This map sits nested in the magazine's almanac section, a monthly department that tells you what's up in the sky and profiles notable celestial events.

A good book that offers similar maps behind one spiral-bound cover is **The Star Book** by Robert Burnham (Kalmbach Books, ISBN 0-913135-00-3). As in ASTRONOMY's monthly almanac, the text points out items of interest, ranging from mythological tales to notable deep-sky objects.

Perhaps the best atlas for learning the constellations isn't an atlas at all. A planisphere shows both the constellations and how they move during the course of an evening, a day, or year. It does this with a rotat-

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6514-M20
M28
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27
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I.4685
6530
B89
B296
B303
6523-M8
Lagoon Nebula

George Greaney

ing disk imprinted with constellations that shows through an opening. Match the month and hour scales to the time you want, and instantly it shows what's up in the sky.

Planispheres typically display stars down to about 4th magnitude, roughly what the naked eye sees from a typical suburban backyard. While there are several on the market, two of the best are the **Miller** and **Phillips's** Planispheres.

Beyond Naked Eye

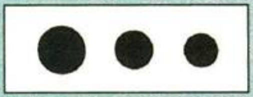
A planisphere's handy ability to dial up the sky for any night of the year never loses its allure for most observers. But when it comes to finding fainter stars and objects with binoculars or a telescope, nothing beats a bona fide star atlas.

A good one to start with is the **Mag. 6 Star Atlas** by Terence Dickinson, Victor Constanzo, and Glenn F. Chaple (Edmund Scientific), which contains 12"

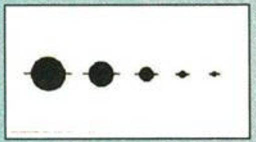
What Is That Symbol?

As with any map, star atlases utilize a legend to help you identify different types of objects. Here is a partial list of some of the most common icons.

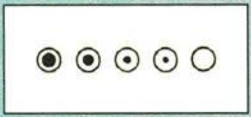
Stars — Black dots on white paper, though some use white dots on a black background. Larger dots represent brighter stars.



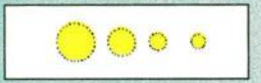
Double and Multiple Stars — Black dots with horizontal lines running through the center. As with other star icons, larger dots indicate brighter stars. Size usually conveys the combined magnitude.



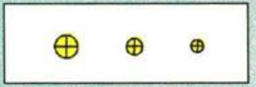
Variable Stars — Open circles with dots in the center. The open circle's size represents maximum brightness, while the inner dot shows minimum.



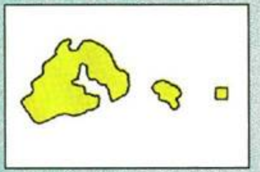
Open Clusters — Dotted circles with a clear or yellow middle. Circle size usually indicates the size of the cluster.



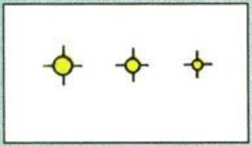
Globular Clusters — Circled cross hairs colored yellow or clear in the center. Size of the circle is proportional to the size of the cluster.



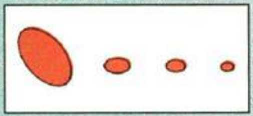
Emission and Reflection Nebulae — Drawn to shape with a common name nearby. Color atlases show diffuse nebulae as green blobs. Smaller nebulae are usually portrayed by a green square the size of which relates angular size.



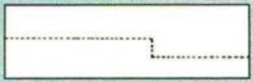
Planetary Nebulae — Circles with radial lines that stick out along the circumference at 90° intervals. Icon size reflects object's angular measurements. These symbols are shaded green in color atlases.



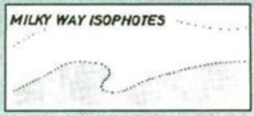
Galaxies — Elliptical in shape with the size of the ellipse usually proportional to the galaxy's actual size, though not always. Often colored red.



Constellation Boundaries — Dashed lines running parallel to lines of right ascension and declination.



Milky Way Boundary — Dotted lines that bound a lighter or darker shade of blue, depending upon the Milky Way's intensity in that particular region of the sky.



Ecliptic — The path that the Sun and planets follow across the sky, represented by a dashed line.

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square maps with an image scale of 8° per inch. A total of 12 charts shows stars down to magnitude 6 and hundreds of deep-sky objects like galaxies and star clusters down to magnitude 10.

This book is ideal for beginners who want to learn how to use a telescope. Useful information is summarized in tables opposite each chart. Fully half of the atlas' pages are devoted to topics a newcomer needs to know such as selecting an observing site, advantages of telescope type, and explanations of magnitude, seeing conditions, and angular measurements. There is also information on the different types of objects to observe.

The Bright Star Atlas (Willmann-Bell, ISBN 0-943396-27-1) is yet another good starter atlas. Designed specifically for new stargazers, this work is full of information that even seasoned amateurs will find useful. The atlas begins with a short introduction on how to use the various charts found throughout the book. Following the introduction are six full-page seasonal star charts that show the brightest stars within each constellation. This gives readers an idea of where constellations are located in the sky and in relation to each other. Keys indicate the time of year each star pattern is visible.

But the nucleus of the book is 10 detailed charts that portray over 9,100 stars to magnitude 6.5 and more than 600 deep-sky objects, including all Messier objects. Unlike the seasonal charts, which show the sky only from 60° north to 40° south, the detailed charts show the entire sky with an image scale of 9° per inch. Several tables summarize data for each object shown on the charts.

Charts for and by Observers

Another atlas worth considering is **1000+: The Amateur Astronomer's Field Guide to Deep Sky Observing** by Tom Lorenzin (1000+, ISBN 0-912081-06-6), who personally observed all 1,000 objects in this catalog with an 8-inch telescope. Seven charts show stars and deep-sky objects to –50° declination using an image scale of 8° per inch. Preceding the chart section is page after page of descriptions based on observations personally made by Lorenzin. Objects are discussed in order of right ascension.

Crossing into the magnitude-8 range is one of the most popular star atlases available, Wil Tirion's **Sky Atlas 2000.0** (Sky Publishing and Cambridge University Press, ISBN 0-933346-33-6). Its 26 charts show some 43,000 stars at the generous image scale of 3° per inch. The atlas also plots 2,500 deep-sky objects.

One drawback is that star symbols are binned in whole magnitude units so, for example, stars between magnitude 2.6 and 3.5 — a full magnitude in brightness — are plotted at the same size. Such a brightness difference, however, is not easy to notice through the telescope.

Jumping one magnitude fainter, we enter the realm of advanced atlases. The best is two-volume **Uranometria 2000.0** (Willmann-Bell, ISBN 0-943396-14-X [vol. 1], ISBN 0-943396-15-8 [vol. 2]), which shows a total of 332,556 stars and more than 10,300 deep-sky objects on 473 charts.

Philips' Planisphere
shows the principal stars visible for every hour in the year
for Latitude 42°N
USA • Southern Europe • Northern Japan
Western Horizon
Eastern Horizon
JUNE
MAY
APRIL

ASTRONOMY: Jim Forbes

A handy planisphere lets you both dial in and learn the constellations for any time of year. Just align the date with the time (left) and then face a direction of sky you want to explore. Planispheres, sometimes called "star wheels," show stars down to 4th magnitude, constellation shapes and names, the path of the planets, and the positions of some brighter deep-sky objects.

Each page measures 9 by 12 inches and covers 12° to 13° of declination using an image scale of 1.4° per inch. Volume one includes the northern sky to –6° declination, while book two delivers the southern sky to 6°.

These editions are accompanied by the exceptional 500-plus-page **Deep Sky Field Guide** (Willmann-Bell, ISBN 0-943396-38-7) which breaks out data on each object found in *Uranometria* by object type, chart by chart.

Getting There from Here

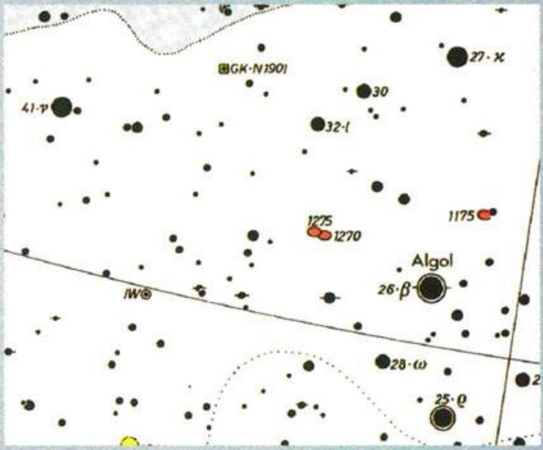
Armed with a flavor for what atlases offer, the next question might be where to get them. If your local bookstore doesn't have them in stock, use the title's publisher and ISBN number to place a special order. Even more convenience, order from ASTRONOMY's book department by calling (800) 533-6644. Also look for book publishers and sellers that advertise in this magazine. Many companies that trade in telescopes and accessories also offer books and atlases.

After purchasing your atlas, step out on a clear night and enjoy. Some observers work through the heavens methodically, surveying every object on, say, page 103 of *Uranometria 2000.0* or chart 22 in *Sky Atlas 2000.0*. Others carefully research their sessions by plotting quarry onto an atlas from catalogs like **Sky Catalogue 2000.0** (Sky Publishing/Cambridge University Press, ISBN 0-521-41743-0 [vol. 1], ISBN 0933346-39-5 [vol. 2]) or *The Deep Sky Field Guide*.

Still other deep-sky watchers just "gauge the heavens," stumbling upon and then confirming an object, not unlike what the 18th-century astronomer William Herschel was doing when he chanced on the planet Uranus in 1781. (See "Free-form Observing," August 1996.)

Regardless of how you use a star atlas, such a map is your passport to a lifetime's worth of fruitful observing, be it with a telescope, binoculars, or unaided eye. □

Mark Coco passed away shortly after penning this article. His contributions to ASTRONOMY *magazine and the amateur astronomy community will be sorely missed.*


41-ν
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32-ι
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1270
1175
Algol
26-β
IW
28-ω
25-ρ
2

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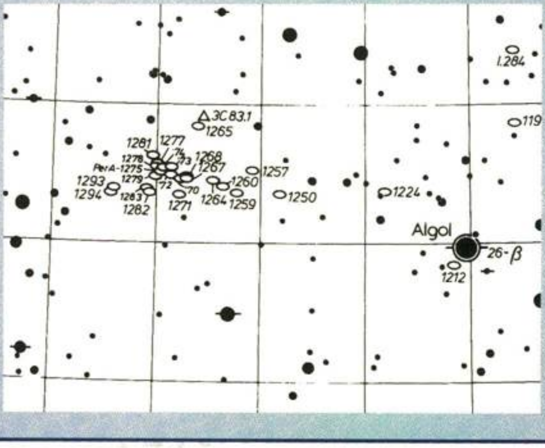
Fainter targets seemingly appear from nowhere on a bigger atlas. Where *Sky Atlas 2000.0* plots two galaxies just east of Algol in Perseus (above), *Uranometria 2000.0* reveals a cluster of faint galaxies (below). *Sky Atlas* balances moderate deep-sky detail with wide views of the sky on 26 charts that show stars down to magnitude 8 and color-coded deep-sky objects down to magnitude 9. All of its deep-sky objects lie within the range of backyard telescopes smaller than 8 inches. *Uranometria* renders the sky on over 400 charts that present stars down to magnitude 9.5 and deep-sky objects as faint as magnitude 13. It is the atlas of choice for owners of large-aperture telescopes.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1250
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Algol
26-β
1212

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Optional Eyepiece	TRUE FIELD	Price
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Wedge for photographing w/8'' LX200	**$139**
7'' LX50 f/15 Maksutov w/wedge ($125 P&S)	**$1795**
10'' LX50, f/10 w/wedge, dec. motor, hand controller ($145 P&S)	**$1695**
10'' LX200 w/computer ($145 P&S)	**$3195**
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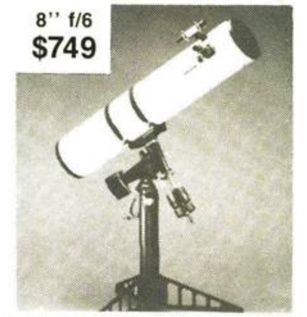

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive & finderscope (equat. only), mount, and 25mm (=48X) eyepiece. New DC motor runs on 4AA batteries.

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12.5'' f/4.8 Dobsonian Starfinder ($95 P&S)	**$895**
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*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $50-$100 higher.

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- "GUIDE" mode leads you to object
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- Motor drive ***not required!***
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- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
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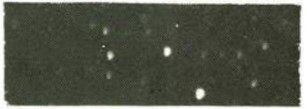

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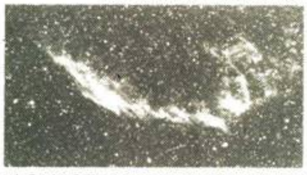

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D-19 B&W Developer	1 gal.	**$6.95**

Observing Hickson Galaxy Groups

An often overlooked catalog holds charming congregations of challenging galaxies for a medium-sized backyard telescope.

by David Higgins

What could possibly beat viewing a galaxy under the crisp blackness of the winter sky? Zooming in on an eyepiece field containing four or five galaxies. Such compact galaxy groups are small knots of galaxies, often interacting, that provide little laboratories for astronomers studying the relationships of galaxies away from the large dense clusters. And the current hot ticket in observing galaxy groups offers 100 compact groups visible in backyard telescopes. Assembled by Paul Hickson of the University of British Columbia in Vancouver, *Atlas of Compact Groups of Galaxies* (221 pp., Gordon and Breach Science Publishers, Basel, Switzerland, 1994, ISBN 2–88449–115–5) contains basic data and images of all 100 groups. We'll explore six Hickson galaxy groups visible in the winter sky, but first, a bit of background.

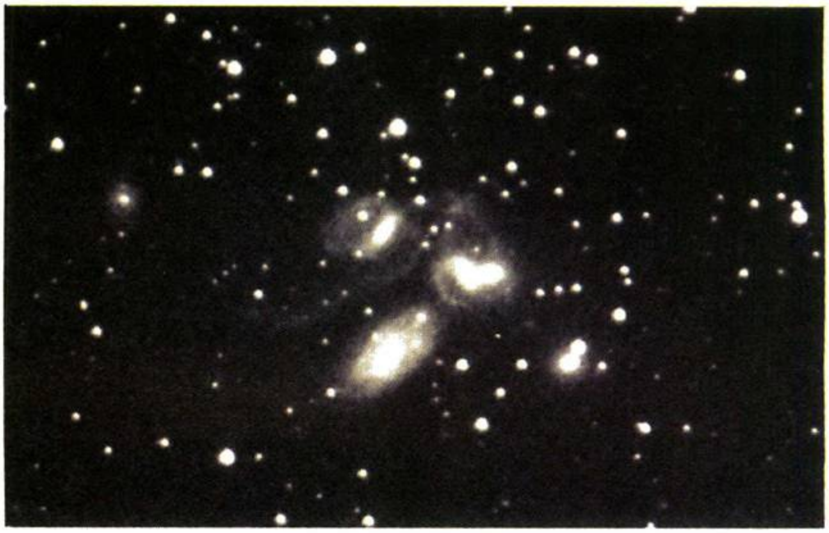
The atlas is divided into several key areas. It provides a brief history of galaxy groups and what astronomers know or what they think they know about these groups. The atlas also yields ample information about the selection criteria Hickson used. Extensive data for each group appears, most of which is of little use to backyard observers — but all the basic observational information like positions and magnitudes appears too. The atlas contains images of every group made with the 3.6-meter Canada-France-Hawaii Telescope on Mauna Kea, Hawaii. A reference section will help those who want additional information.

Despite the fact that "Hickson galaxy group" sounds pretty far off the beaten path, a number of groups hold an NGC or an IC galaxy as the brightest member and are not terribly difficult to track down. The problem comes in viewing the other group members: They range from UGC galaxies to extremely faint galaxies that have some exotic number or classification or none at all. Some groups have 12th-magnitude galaxies and some are fainter than 16th magnitude. Although some of the groups are visible in an 8-inch scope, with many we're talking observing with a 12-inch or 16-inch instrument — or larger.

Keep a few tricks of the trade in mind. First, observe from as dark a site as you can. There's no substitute for a really dark sky. Once you've located a group in the eyepiece don't hesitate to use high magnifications. This not only provides a larger image but darkens the sky around the group, making it easier to see. Averted vision — glancing to one side of the eyepiece field and thereby using your eye's sensitive rods — will also help in detecting those fainter group members. And of course the larger the scope, the better the chances of seeing the really faint galaxies. I use a 24-inch f/4 reflector with a 12mm Nagler that gives me a magnification of 203x and a 24' field of view.

The best known galaxy group in this catalog is **Hickson 92**, better known as Stephan's Quintet, which lies in the constellation Pegasus about 5° north and a little west of Matar (Eta [η] Pegasi). When you look into the eyepiece, the first thing you'll notice is a fairly large, fuzzy patch of light. This is NGC 7320, the largest galaxy in the group. Measuring 2.2' by 1.2' and glowing at magnitude 12.7, NGC 7320 is an Sd spiral that shows some detail in a large scope. The galaxy is elongated southeast-northwest and has a bright core surrounded by an uneven haze. Look carefully to see some hint of spiral structure and a mottling on the northwestern side of the galaxy. A field star can be seen a few arcseconds southeast of the nucleus.

Hickson 92, also known as Stephan's Quintet, offers five challenging galaxies clumped together in northern Pegasus.



Martin C. Germano

Hickson Galaxy Groups

Hickson	R.A.(2000.0)	Dec.	N	M_B	Brightest	Mean Sep.	Con.	Notes
7	0h36.8m	0°36'	4	11.8	NGC 192	149,000 ly	Cet	
10	1h23.4m	34°27'	4	11.7	NGC 536	303,000 ly	And	
16	2h07.1m	−10°23'	4	11.6	NGC 835	145,000 ly	Cet	Arp 327
92	22h33.7m	33°42'	5	11.5	NGC 7320	92,000 ly	Peg	Stephan's Quintet
93	23h12.8m	18°53'	5	11.8	NGC 7550	230,000 ly	Peg	Arp 99
96	23h25.5m	8°30'	4	13.0	NGC 7674	98,000 ly	Peg	Arp 182

Hickson: Designation in the Hickson catalog. R.A. and Dec.: right ascension and declination coordinates in epoch 2000.0. N: number of galaxies. M_B: total blue magnitude. Brightest: Brightest galaxy in the cluster. Mean Sep.: Mean separation of the group's galaxies in light-years. Con.: Constellation. Notes: Other designations.

An interacting pair of galaxies lies a few arcminutes northwest of NGC 7320. Separately, NGC 7318B and NGC 7318A are each a little smaller and dimmer than their neighbor to the southeast. But together they are a little larger and brighter than NGC 7320. NGC 7318A glows at magnitude 13.3 and measures 1.0' across. NGC 7318B lies east of NGC 7318A and glows at magnitude 13.1. Measuring 1.9' by 1.3', its core is brighter than the haze that surrounds it. With high magnification, a hint of a spiral arm can be seen east of the galaxy's center.

About 5' northeast of this interacting pair you'll find the barred spiral galaxy NGC 7319. Measuring 1.7' by 1.3' and glowing at 13th magnitude, NGC 7319 is elongated a little northwest-southeast. At high magnification, with averted vision, a hint of outer arm structure is visible to the northeast. NGC 7320C is a smudge of light faintly glowing at magnitude 15.5 and measuring only 0.7' by 0.6'. The final galaxy in Hickson 92 is NGC 7317, a small haze measuring 1.0' by 0.8' and glowing at magnitude 13.6. It lies some 8' southwest of the interacting pair NGC 7318A and NGC 7318B. I see no detail in this object but its nucleus appears slightly brighter than the surrounding haze.

Also in Pegasus, inside the Great Square and 4° northeast of Markab (Alpha [α] Pegasi), is **Hickson 93**. The brightest galaxy in this group is NGC 7550, an elliptical measuring 1.7' by 1.6' and glowing at magnitude 12.6. A few arcminutes west lies NGC 7547. Glowing at 14th magnitude and measuring 1.0' by 0.5', this spiral is elongated east-west. A few arcminutes north of NGC 7550 you'll find NGC 7549. This 13th-magnitude spiral measures 1.3' by 0.6' and is oriented north-south. The center is slightly brighter than the surrounding haze. CGCG 454–15 is a magnitude 15.2 haze that shows no detail at all. Nearby lies NGC 7558, a magnitude 15.4 object spanning just 0.4'.

Hickson 96 lies about 2½° north of Theta (θ) Piscium, just over the border with Pegasus. At magnitude 13.5, NGC 7674 is the brightest of the group, and it spans a mere 1.2' by 1.1'. Its nucleus is pretty bright: With high magnification you can just catch a hint of some mottling and arm structure. A few arcseconds east lies Hickson 96C, a small oval haze that requires steady seeing and dark skies to pick up. It glows at magnitude 15.6. Some 5' east is NGC 7675, a magnitude 14.4 fuzzball measuring 0.7' by 0.4'. The group's last object is Hickson 96D, a magnitude 16.5 object beyond the reach of most backyard scopes. Lying in the same field, some 8' north of NGC 7674, is CGCG 406–113. This magnitude 15.6 galaxy is physically unrelated to the group.

Move to the galaxy-rich constellation Andromeda to find **Hickson 10**. Look for the group about 4° southeast of Mirach (Beta [β] Andromedae). NGC 536 is the brightest member, glowing at magnitude 12.6 and measuring 3.1' by 1.6'. A few arcminutes north you'll see NGC 531, a 14th-magnitude spiral spanning 1.9' by 0.5'. Southeast of NGC 536 lies the most challenging galaxy of the group, NGC 542. This elongated haze glows dimly at magnitude 14.7 and measures 1.0' by 0.3'. Also in the group is NGC 529, a 12th-magnitude galaxy covering 2.4' by 2.1' of sky.

Cetus holds the final two Hickson galaxy groups for tonight's viewing. In northwestern Cetus you'll find **Hickson 7**, a collection of four spirals. The brightest member is NGC 192, a 13th-magnitude object measuring 2.3' by 1.2' with a bright middle. Other members include NGC 196, NGC 197, and NGC 201. Some 5° east of Zeta (ζ) Ceti lies **Hickson 16**, a group of four 14th-magnitude galaxies. The brightest member is NGC 835, a magnitude 12.7 object spanning 1.9' by 1.6'. The others are NGC 833, NGC 838, and NGC 839.

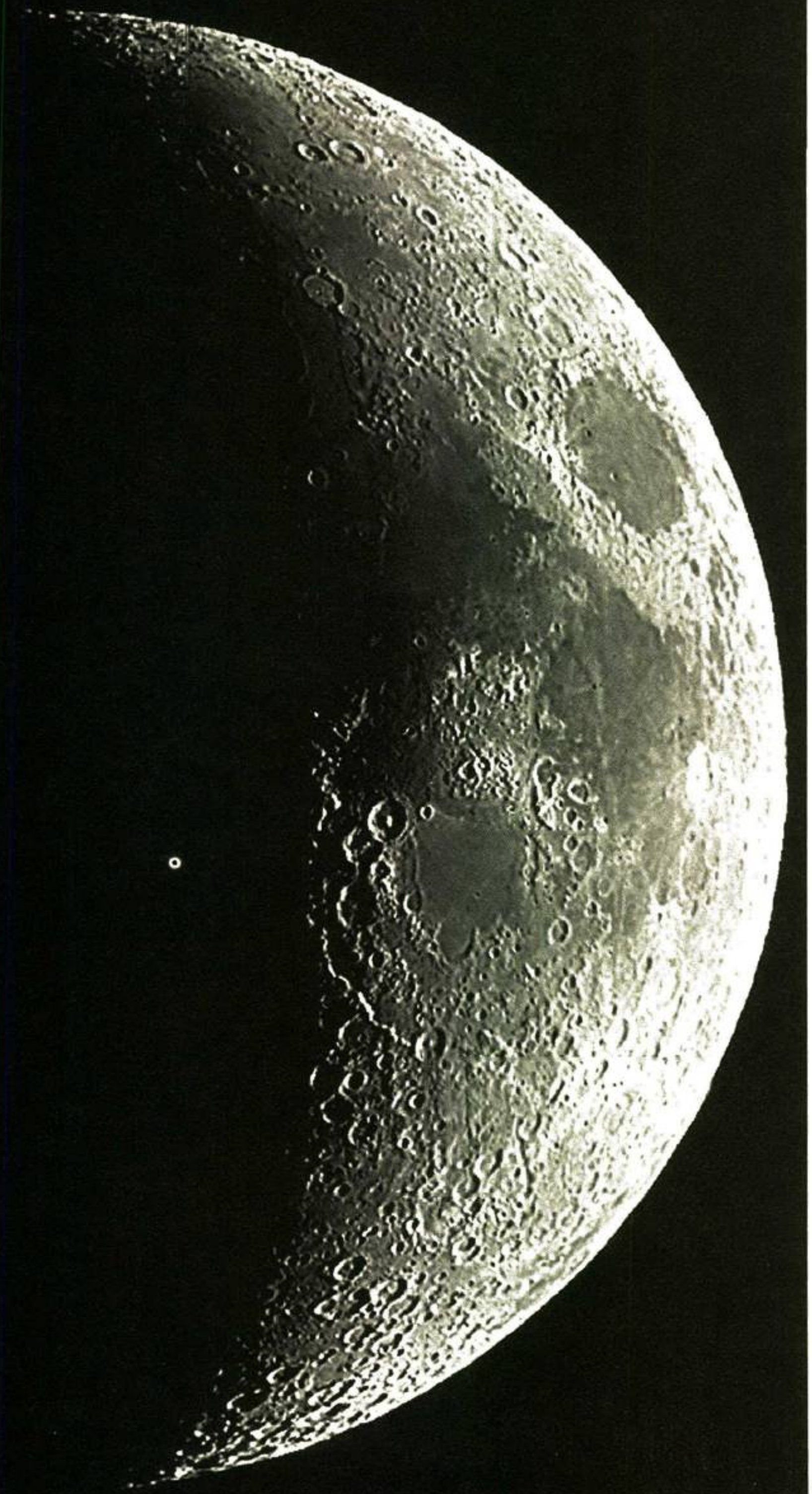
As you go after these challenging little groups, remember that they're faint and require optimum conditions as well as a sizeable telescope. Don't be dis- couraged if at first you don't succeed. When you do get some good views, you'll appreciate what the term "faint fuzzy galaxy" is all about. ☐

David Higgins is an experienced deep-sky observer and a frequent contributor. His last article was "Faint Balls of Fire" (September 1996).

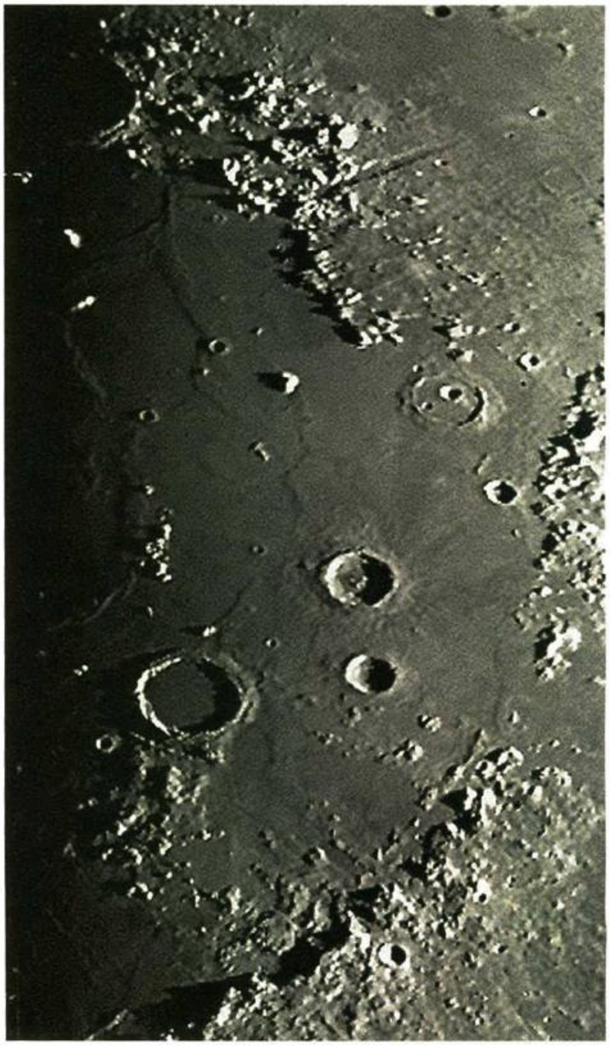
PIECE -by- PIECE

CCD users nab stunning mosaics of the night sky, thanks to a simple technique and some off-the-shelf computer software.

by Gregory Terrance and Ray Ciccariello



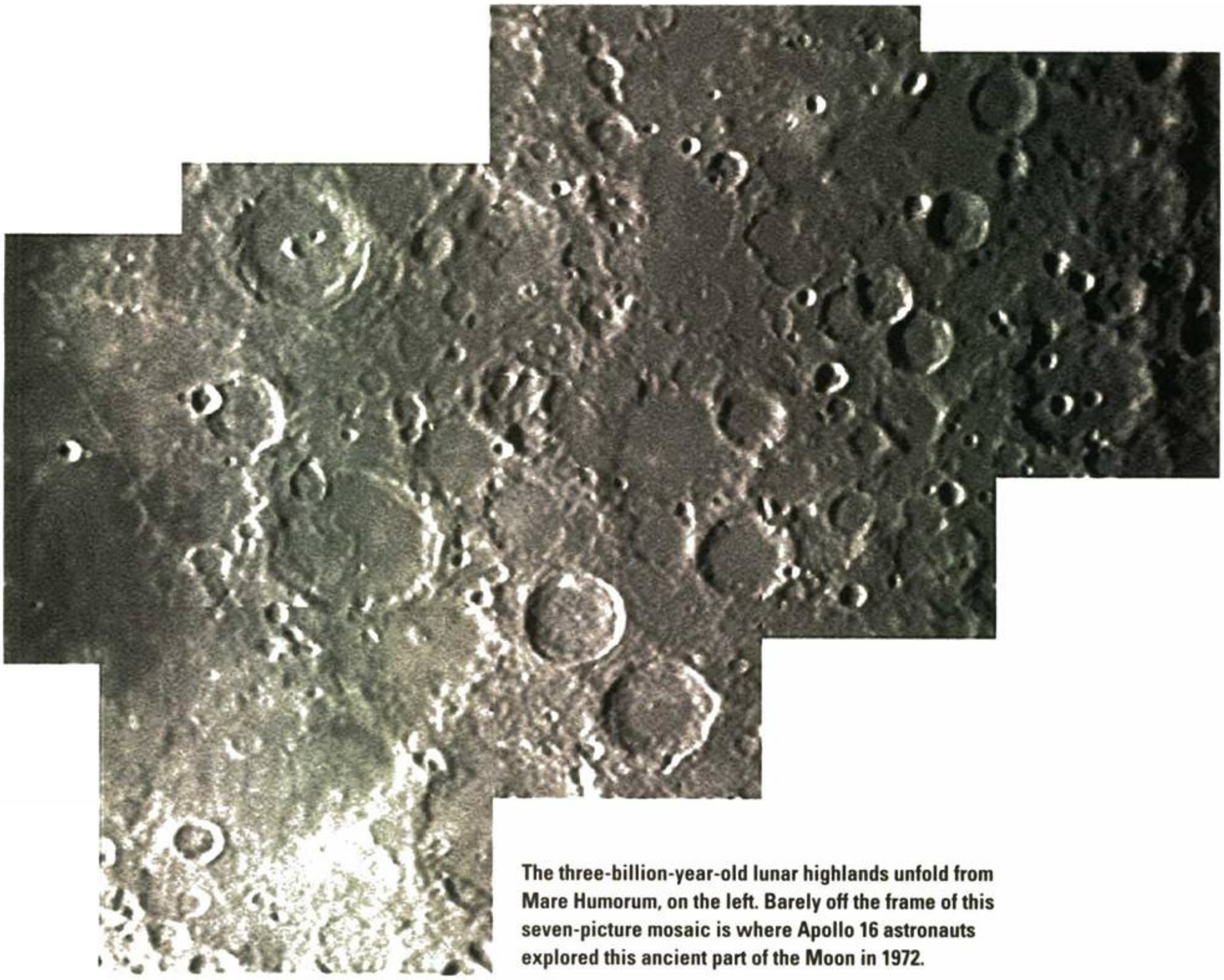
Mosaics broaden a CCD camera's horizons. This view of a waxing crescent Moon is actually made up of 25 separate images shot through a 5-inch f/10 telescope.



The eastern ramparts of our Moon's Sea of Rains fill this 10-picture composite taken with an Lynxx PC CCD camera through a 16-inch f/5 telescope. A CCD's enhanced digital imagery brings out detail down to three kilometers across.

All images by Gregory Terrance

Astrophotography



The three-billion-year-old lunar highlands unfold from Mare Humorum, on the left. Barely off the frame of this seven-picture mosaic is where Apollo 16 astronauts explored this ancient part of the Moon in 1972.

During the 70s and 80s, planetary probes like Viking and Voyager gave us fantastic views of other worlds. Today we enjoy stunning images from the Hubble Space Telescope. Some of the splashier pictures we see from these programs are in reality a patchwork of several images electronically stitched together.

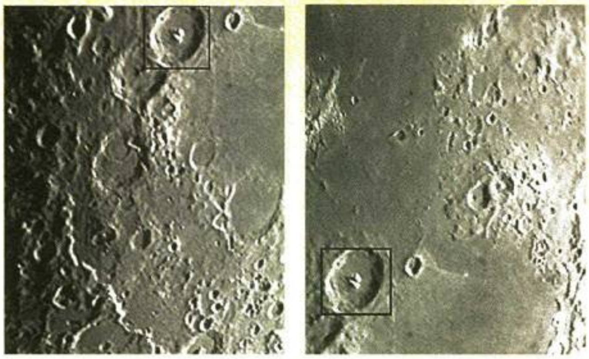
The same technique that lets professional astronomers merge their pictures is available to anyone with a personal computer. It's called "mosaicking," and for the CCD astrophotographer it works around the limitations of a small CCD chip. Mosaicking captures wide regions of the sky, like sprawling galaxies and huge tracts of the Moon, areas often overlooked because of their sheer size.

The Stuff of Mosaics

Size lies at the heart of the CCD enthusiast's dilemma. Whereas conventional film captures whole sections of the sky rather easily, CCD chips are small, typically ¼ to ⅓ the size of a 35mm frame of film. So if a CCDer wants to image larger areas, he has two choices: widen a telescope's field of view or electronically splice smaller views together.

But here's where mosaicking offers a distinct advantage. Aside from accommodating larger targets, mosaics yield higher resolution. In mosaics, pixels, the tiny dots that make up a CCD's image, cover smaller portions of the overall object to yield finer detail. Shooting that same object using the telescope and a focal reducer makes a given pixel cover a wider por-

Mosaicking 101



Prepare the Pictures:

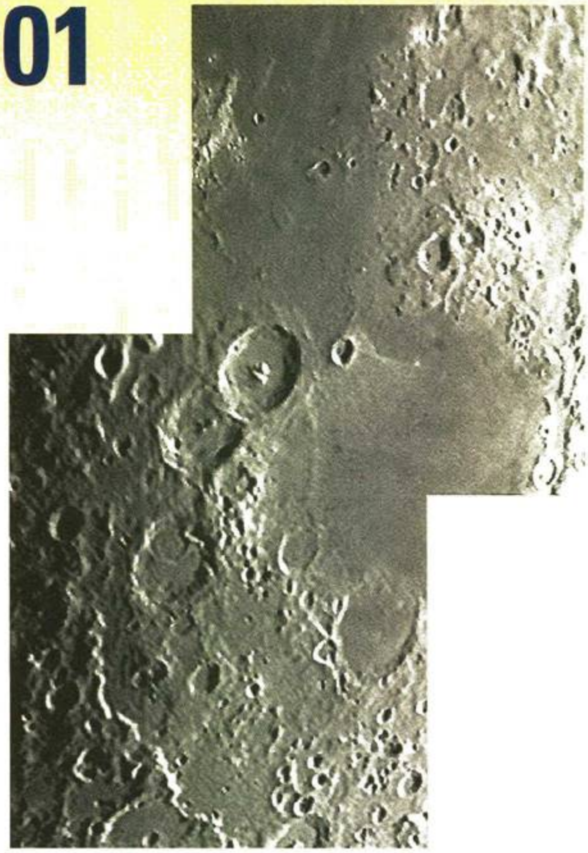
1 **Calibrate raw images (e.g., flat fields, dark frames, etc.).**
2 **Convert images into formats readable by your processing software.**
3 **Crop images if necessary.**
4 **Use pixel patterns as guide posts to match pixels on each image.**
5 **Stitch or Combine the two images.**
6 **Match the brightness of the two images.**

Start Stitching:

1 **Select and open two images.**
2 **Locate a common area of overlap.**
3 **Zoom into the overlap area of each image.**

Build a Mosaic:

1 **Repeat above steps until the mosaic is complete.**
2 **Perform final processing on the finished image.**



Sprawling Theophilus crater serves as a calibration feature (above, left) for an eight-tile, 840-kilometer-long window on the Moon's tortured terrain (above).

tion of the target, and fine detail gets lost. Focal reducers also suffer from light loss, distortion, and vignetting. Factor in all these concerns, and creating a mosaic is a valid option regardless of what size CCD chip you have.

Where to Start

Keep your initial foray in CCD-mosaic photography as simple as possible. Before trying your hand at more complex mosaics, first learn how to assemble two images into a single, seamless image. Starting with a 25-image lunar mosaic will likely lead you to frustration.

Crucial to any smooth-working mosaic is image overlap. A good rule of thumb is to overlap images by 10 to 20 percent as you shoot them. Look for a specific star to match up deep-sky frames and, in the Moon's case, use craters as reference features.

Balance is also an operative word here. Overlapping too much does not use the CCD chip's size effectively and requires more images to cover the object. Too little overlap and you may not have a common point of reference to put the images together.

It's also important to keep exposure values to within 10% while shooting overlapping frames. Different exposure times make it difficult to match the con-

Mosaicking software

Picture Publisher 5.0
Cost: $79.95
Minimum requirements: Windows 3.1, 386DX w/ math co-processor; 8-15 Mb of free space; DOS 5.0; 8 Mb RAM

Picture Publisher 6.0
Cost: $149.95
Minimum requirements: Windows 95 or NT; 486DX; 30-40 Mb of free disk space; 8 Mb RAM

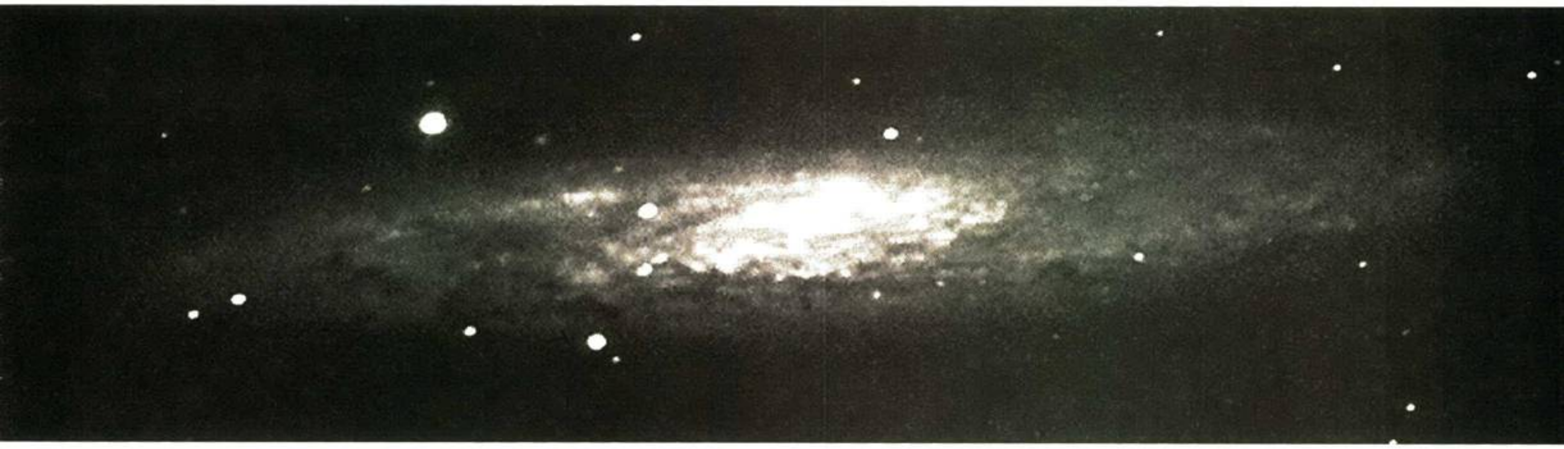
Fractal Design Painter *
Cost: $549 (List)
Minimum requirements: 486, 8Mb RAM

Corel Graphics Pack
Cost: $89.99
Minimum requirements: 486DX2; 66 MHz; (Photo-Paint 6 should also be installed)

Ulead Systems Photo Impact
Cost: $99.99
Minimum requirements: 486DX with 8 Mb RAM

Adobe Photoshop *
Cost: $89.99
Minimum requirements: 486DX with12 Mb RAM

*** Available for Macintosh**



Runaway star factories clump along the galactic plane of NGC 253, a galaxy in the autumn constellation Sculptor. Two images make up this composite taken through an 16-inch f/5 telescope.

trast and brightness of each frame during assembly. The sky also won't be uniformly black in deep-sky mosaics if exposures aren't similar.

While it's relatively easy to keep exposures consistent for deep-sky objects, it's more difficult for lunar work. The Moon has a wider range of brightness variation than most deep-sky objects. To cope with this, set your exposure value so the brightest areas of the Moon are not oversaturated and the darker areas show adequate detail. Stop down the telescope with an aperture mask or experiment with filters.

Regardless of what and how you expose, avoid rotating your camera between each picture. Physically moving the camera makes electronic assembly more difficult and renders all but one of your camera's flat field calibration frames useless.

Crop and Clean Up

Many software packages on the market can create mosaics from multiple images. As the table shows, the majority are Windows-based, but there are also a couple for Macintosh. Although our examples use *Picture Publisher 5.0* from Micrografix, the same procedures apply to software that use comparable tools and techniques. Refer to your software's help menu or user manual for the specific commands to perform these steps.

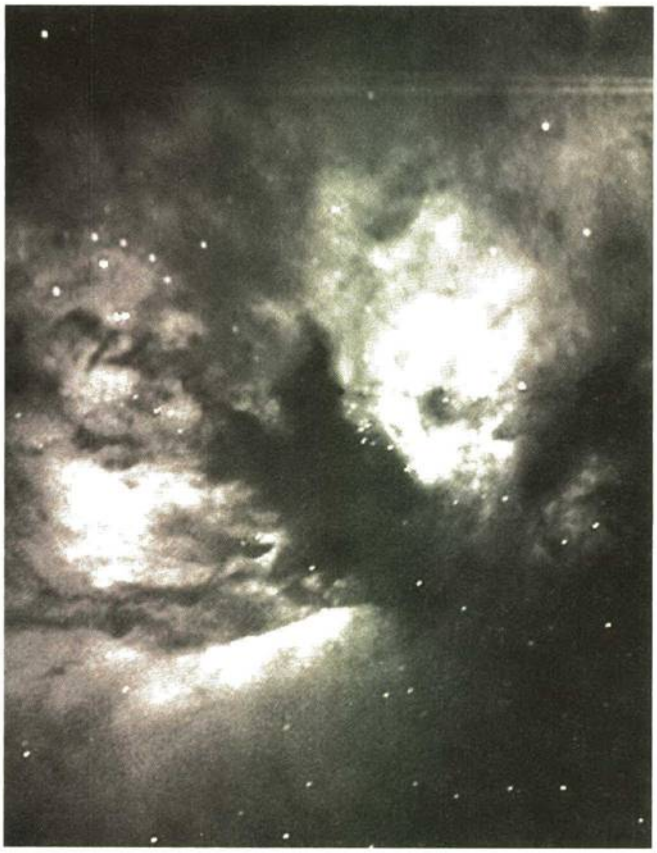
After shooting sections of the mosaic, the first step before assembly is to remove unwanted noise and defects from each of the raw images. Subtract out your CCD's flat- and dark-field frames as you would with any other image. Once the raw images are cleaned up, convert them into a format readable by the image-processing software you're using.

There's one more "clean-up" step after you import the image into the program. If your camera has edge or row defects, crop out any bad areas before making a mosaic. For example, the camera that took the lunar images shown on these pages is an older one that produces superb images, but has defects in its CCD array. We cropped out these defects prior to assembly. Today's newer cameras should not have this problem.

The cropping procedure is simple in *Picture Publisher 5.0*. Open the Mask menu and use the Mask Tool to select what portion of the image you wish to keep. Next, use the Crop to Mask command to eliminate any of the image's unwanted edges, while keeping a portion for assembly. Crop with care; keep a common reference point that overlaps with subsequent frames. Now you're ready to assemble the images.

Assembling the Big Picture

Open the first two images you want to assemble. Place any overlapping areas, such as a star field or



The Flaming Tree Nebula (NGC 2024) is a cloud of gas that glows under the ultraviolet light of a nearby star. A pair of CCD frames comprise this photo taken with a SBIG ST6 CCD camera through an 8-inch f/5 telescope.

group of craters, side by side. If you are assembling deep-sky frames, select a dim star that covers only a few pixels. This allows for a more precise line-up between pictures. In the Moon's case, choose lunar craters that are small and have distinct markings.

Zoom into each area using the View Tool until you see the individual pixels on both images. Stars and craters will not be recognizable at high magnification, but you will be able to see the pixels and the patterns that they form. Don't be surprised if the two enlarged images don't look exactly the same. The effects of atmospheric turbulence alters sharpness and shading.

Carefully examine and compare both enlarged views. Select corresponding pixels from each image. Mark these pixels using the "Stitch" command, then match the brightness level between the two images. Now combine the two together and save them as a new image.

Repeat these steps for subsequent additions. If you are assembling a large number of images, save the combined image before adding another frame. That way, if you make a mistake there's always a previously-saved image to reuse.

Continue this process until the mosaic image is complete. The combined image is now ready for final processing adjustments such as cropping, sharpening, and contrast changes. These gross adjustments should wait until you finish assembling the entire mosaic: otherwise, individual pieces will not appear the same and the mosaic will look piecemeal.

Taming the Complexities

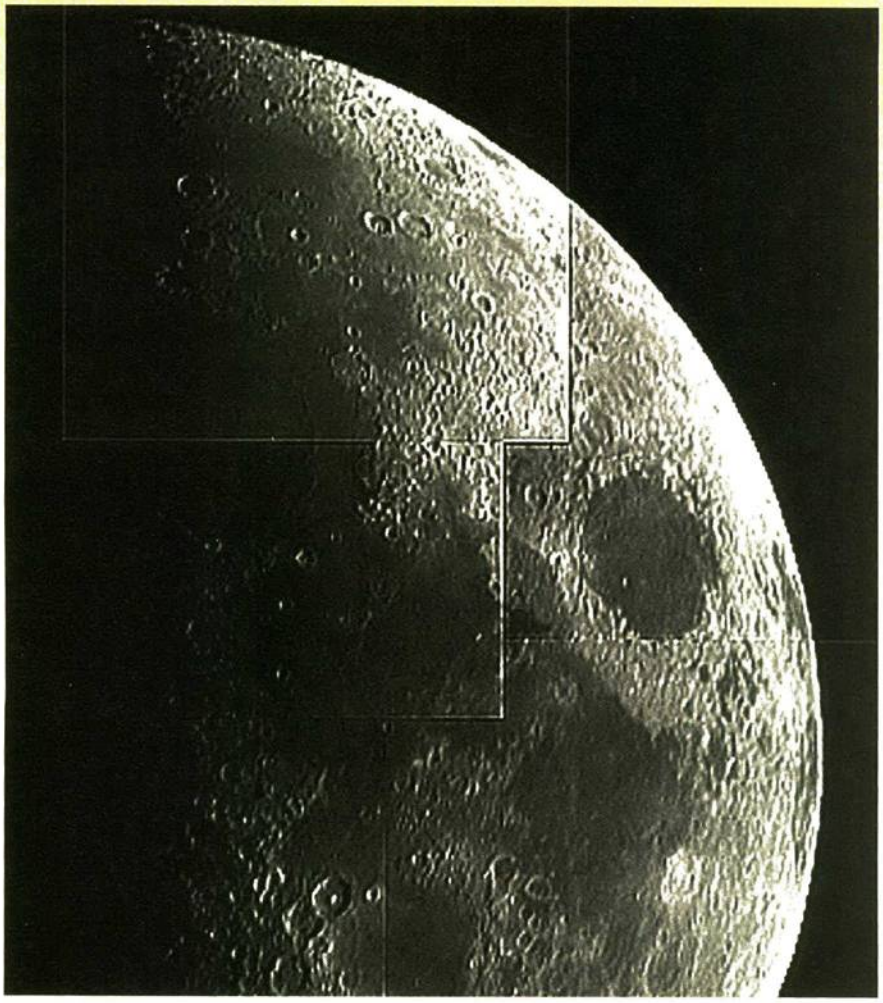
After mastering simple mosaics, try the same techniques on tricolor and complete lunar disk images. Full-disk lunar mosaics may require 20 or more separate images. The actual number depends on your CCD chip size and telescope focal length.

Assembling a full-disk image of the Moon can be a daunting process but the results are rewarding. Also, getting enough images to cover the entire disk requires some care. It's easy to miss a section.

If you have taken tricolor images in the past, a color mosaic may be the next challenge. As the name implies, a tricolor mosaic uses three distinct images — one red, one green and one blue — for each tile in a mosaic.

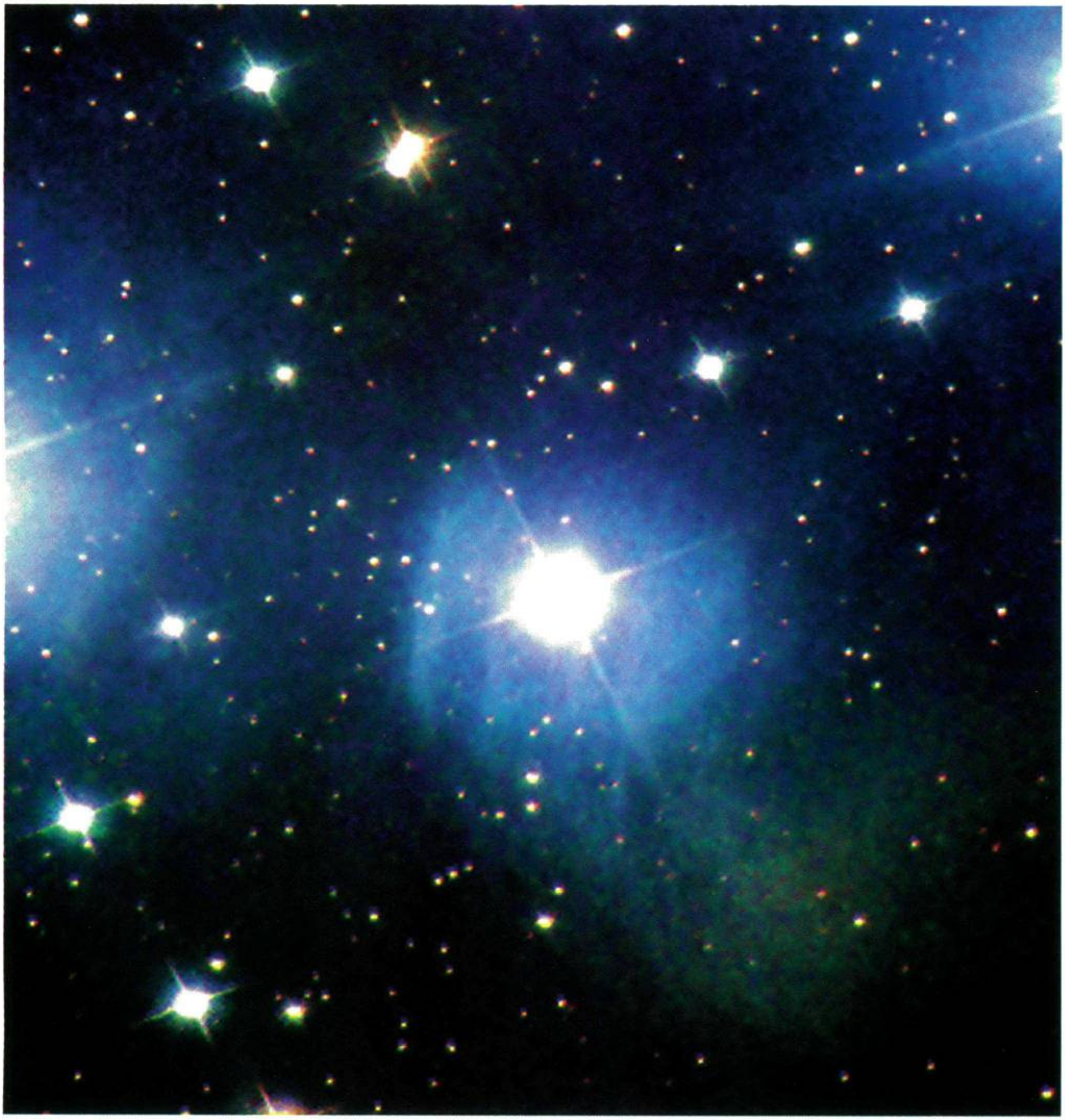
This means a single color mosaic requires three times as many images than what's needed for a standard black-and-white picture. Shooting through color filters is nothing new if you already have some experience with color imaging.

Toward a Better Mosaic



Make doubly sure exposure values for each picture in a lunar mosaic don't vary by more than 10 percent. Here a first quarter Moon's northern hemisphere looks like an obvious patch quilt.

- Acquire flat-fields frames and dark frames.
- Take enough frames to cover the object completely.
- Overlap images by 10–20%.
- Use the same exposure values between images.
- Do not rotate the camera between images.



This ambitious three-color composite uses two separate exposures, each taken through a red, green, or blue filter with a SBIG ST6 CCD camera on an 8-inch f/5 telescope. The final result shows Merope, a member of winter's Pleiades, shining through bluish tendrils of interstellar dust.

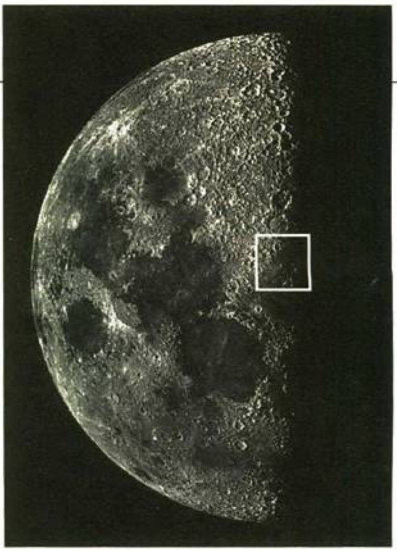
What's new, however, comes in assembling the mosaic. Each colored layer of the final mosaic gets put together from its constituent tiles before combining each colored layer into a final tricolor image. This requires three times the work and patience. To some extent, the nuances of color assembly will depend upon what software you're using.

Many of the techniques described here are generalized due to the enormous variety of image processing software available. Don't be afraid to experiment and develop your own techniques. This alone will guarantee countless hours of fun, piecing together your own astronomy jigsaw puzzle.

Just like the pros who use the Hubble Space Telescope, you'll be stitching together a little slice of the sky to discover sights you've probably never noticed before. Thanks to the capabilities of today's software, you'll be doing image assembly and processing that up until now was only available to scientists who worked on Viking, Voyager, Galileo, and the Hubble Space Telescope. ☐

Terrance (gregoryt@frontiernet.net) and Ciccariello (raycicc@aol.com) welcome any comments or questions on digital mosaicking.

Exploring Sinus Medii



Lick Observatory

One small patch of lava near the center of the Moon's face contains fertile ground for telescopic exploration.

by Robert Burnham

When First Quarter Moon next rolls around — or on the night before Last Quarter — aim your telescope at the middle of the lunar disk. There you'll find a small, gray expanse called Sinus Medii, or the Central Bay. This little region only 350 kilometers long contains features well worth exploring over a couple of evenings.

Let's start with Triesnecker, an impact crater about 25 km in diameter. It's easy to locate because it stands alone in the center of Sinus Medii. When seen at local sunrise or sunset, the crater appears like a pool of ink. While the crater's interior is hidden, the low Sun angle reveals the rumply hummocks of ejecta around it. It's not hard to envision the impact throwing a blanket of debris over the local landscape.

As the Sun rises, it picks out terraces on Triesnecker's interior walls and details on its floor. The terraces probably formed in the first few minutes of the crater's existence, as curving slices of wallrock slumped after being heaved up in the impact. The floor contains a central peak, which sprang up when the ground rebounded after impact, and evidence of flooding, most probably by rock melted in the impact. While not as intricately detailed, Triesnecker resembles a 1/4-scale-model of the more famous crater Copernicus.

Adjoining Triesnecker on the east is a 200-km-long network of intersecting cracks and grooves. These are called rilles by lunar geologists. The Rimae Triesnecker meander here and there, but generally north-south. They are wide and shallow, as if the ground had been pulled slightly apart and skinny portions of surface dropped into the cracks — which is what geologists believe occurred.

The Triesnecker rilles test telescopic seeing: They vanish when seeing isn't topnotch. If you can't discern them clearly, try waiting for moments of good seeing (which come and go), or check to see if your scope is poorly placed. For example, avoid looking out a window or viewing across pavement or rooftops heated by the Sun. (If all else fails, lower the magnification — or return on another night.)

Looking northeast from Triesnecker leads your eye to a remarkable structure, one so linear and regular that it's hard to believe it isn't artificial. Hyginus crater stands where two straight rilles meet at an obtuse angle; the 10-km crater gives its name to the whole feature. Spend some eyepiece time here. In good seeing the rille looks like a chain of craters; excellent seeing shows portions of flat floor in the rille between the craters.

Hyginus itself couldn't differ more from such typical impact craters as Triesnecker. Seen at high power, Hyginus has a smooth flat floor, clean unterraced walls, and no surrounding apron of debris. If rocks could speak, those of Hyginus would use hushed tones, befitting their geologically gentle birth.

For all the rilles' visual differences, lunar geologists believe the two systems have the same origin — tension cracks followed by collapse. In the case of Hyginus, the northwest arm lies radial to the Imbrium basin, and it's possible that this section of rille formed along fractures made when that Moon-shaking impact occurred. But what about the eastern arm? Its alignment points to no place in particular, and its provenance remains unknown.

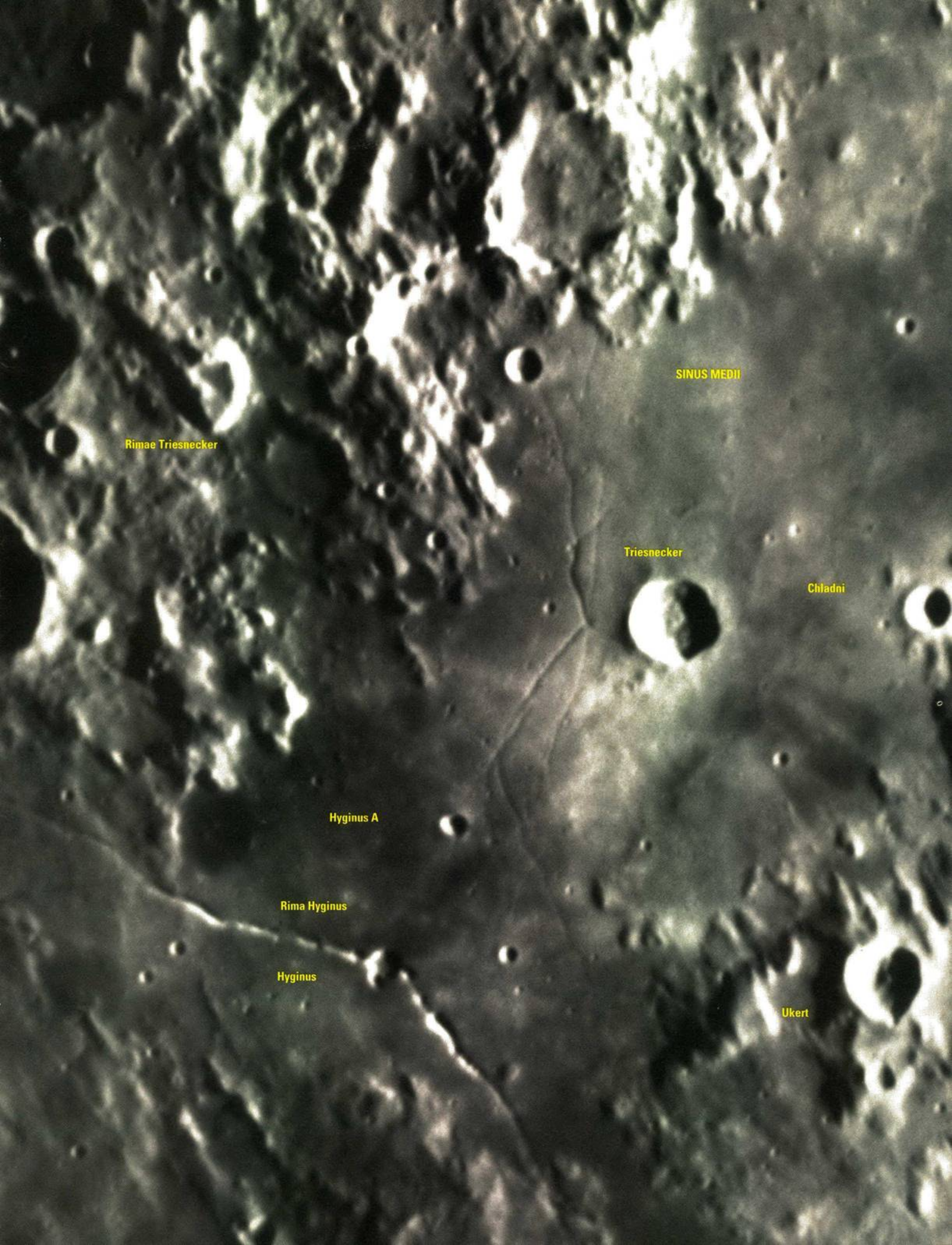
Now drop back in magnification to see all of Sinus Medii. Note how the entire region looks as if someone dragged a coarse rake across it from northwest to southeast. Actually, that's not unlike what happened. When a small asteroid gouged the Imbrium basin, it sprayed debris in ballistic paths that scoured much of the Moon's near side. Lying close to the impact site, the high ground here took many grazing hits that left a telltale pattern.

The southeastern shore of Sinus Medii, scientists think, is a relic ring of that ancient basin-making impact. Easily overlooked, Sinus Medii thus preserves links to key events in lunar history — and provides a fertile ground for any Moon explorer's imagination. □

Robert Burnham is writing a book on Comet Hale-Bopp for Cambridge University Press, due next spring.

The Moon's Central Bay holds a variety of features, including the startling rilles around Hyginus and Triesnecker.

Christian Arsidi


SINUS MEDII
Rimae Triesnecker
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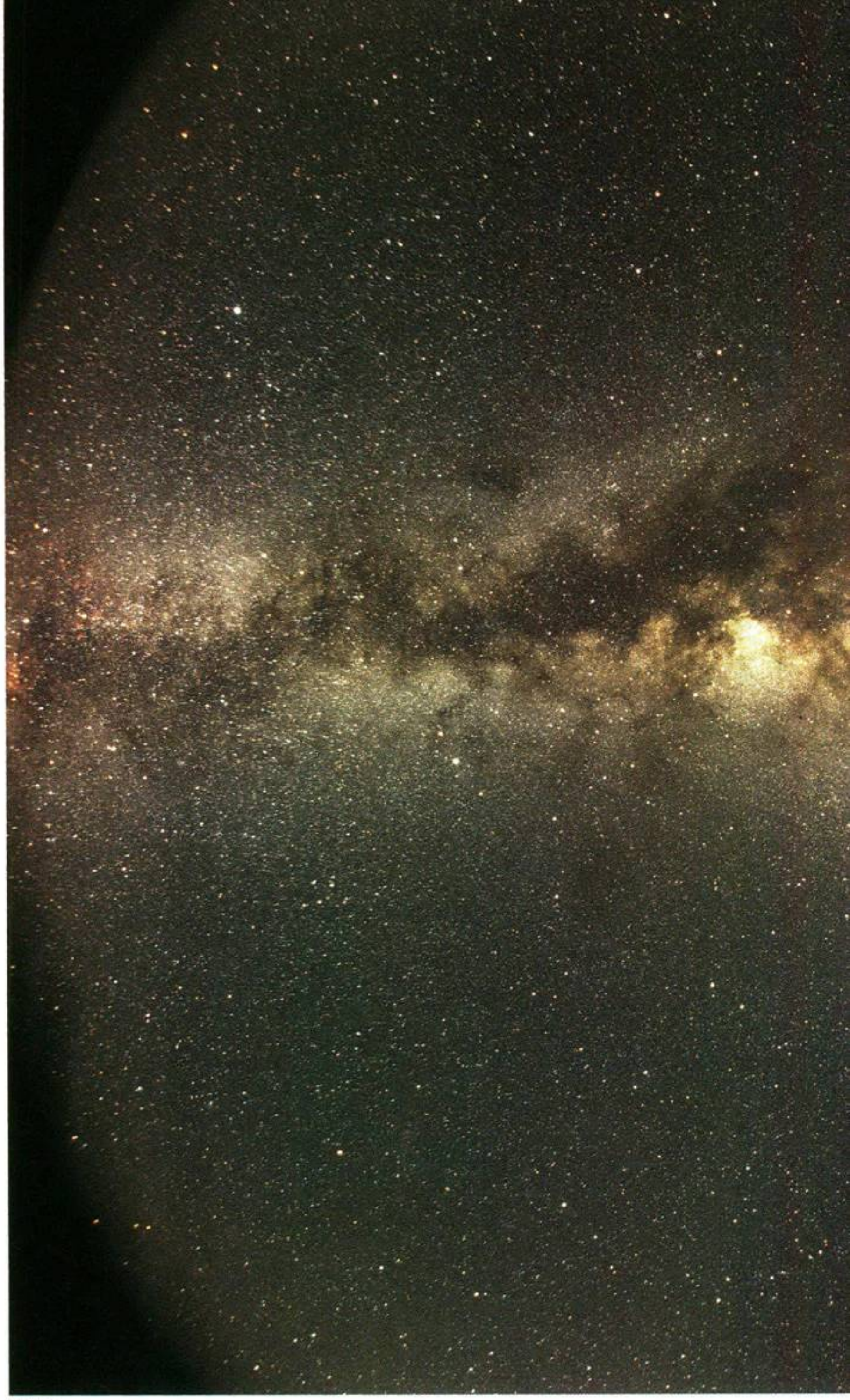
The Galaxy from Within

A spectacular fisheye-lens photo of the Milky Way reveals the Galaxy's intricate blend of stars, gas, and dust.

by David J. Eicher

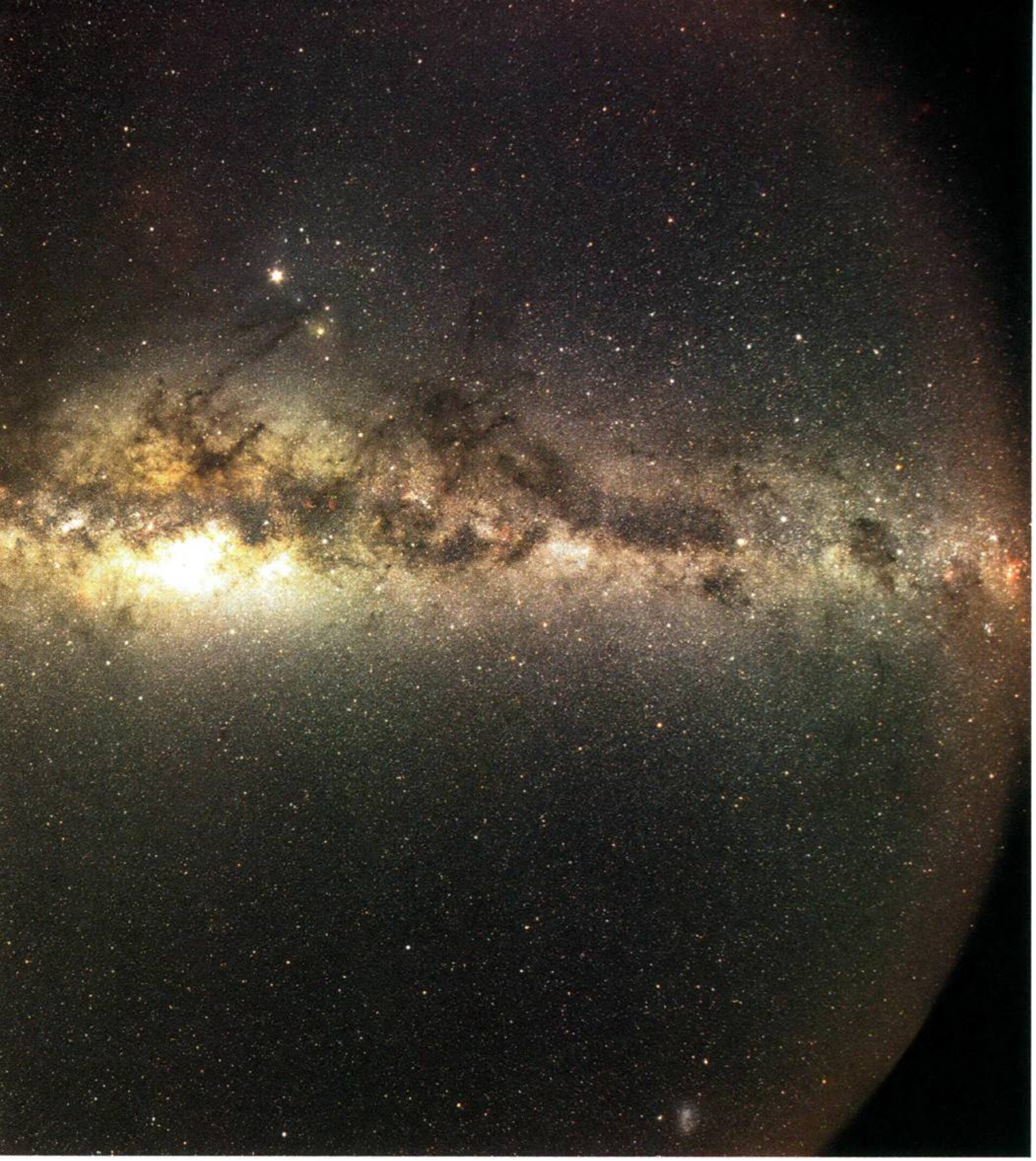


Dirk Hoppe

Any picture of an edge-on galaxy instantly invokes a sight familiar to backyard astronomers: a thin band of light bulging slightly toward the center, bisected by a broad band of dust. It's not unlike the view on these pages. Here, though, we are seeing our own Galaxy viewed from within. The similarity comes from seeing a bright bulge of light toward the galactic center, the light from countless, unresolved stars in the Galaxy's disk, and myriad clouds of black dust lying between the solar system and the surrounding spiral arms. It's a dizzying three-dimensional picture puzzle with many elements, all captured in only two dimensions on a photographic print.

The riveting detail in this image requires some explanation. The photographer, German backyard astronomer Dirk Hoppe, traveled to the pitch-black skies of Namibia in June 1995. He took his 6 by 6 cm medium format camera and a 30mm f/3.5 lens along on the African journey. After setting up in the Namibian desert, Hoppe loaded the camera with Fuji Super HG 400 film and exposed for 150 minutes, creating this stunning portrait. The combination of a wide-field lens, high resolution color film, and a long exposure created the amazing result.

The brilliant glow of the galactic center in Sagittarius lies at the photograph's center, and the coverage of constellations extends



from Cygnus (at left) to Carina (right). A bright nebula, a star forming factory, marks each constellation — the Lagoon Nebula at center, the North America Nebula at left, and the Eta Carinae Nebula at right. Numerous clusters and nebulae pepper the arch of the Galaxy in between, as with the Galactic Dark Horse (on his back, above center), the Scutum star cloud (left of center), the faint bubble surrounding Zeta Ophiuchi (above center), and the Coalsack, near the right-hand edge. Other features are present, too: the Small Magellanic Cloud, one of the satellite galaxies of the Milky Way, floats majestically at bottom right, and wandering Jupiter outshines all other objects in the photo, above and slightly right of center. Comparing the image to a star atlas shows myriad clusters and nebulae.

All through this image the Galaxy is going about its business. Stars are being born; others are dying. All are slowly and grandly rotating about the Galaxy's center in this disk. Tuck this image of the Galaxy into your mind the next evening you wander out and look skyward. It starkly reveals how our galaxy is a richly detailed, crowded, and busy place. ☐

David J. Eicher is managing editor of ASTRONOMY. *He views the splendors of the Galaxy whenever possible with a variety of telescopes.*

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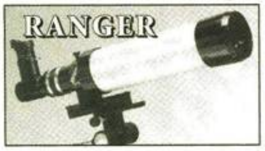

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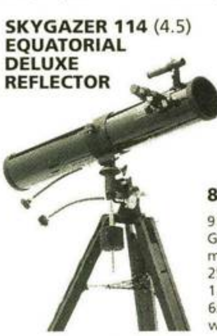

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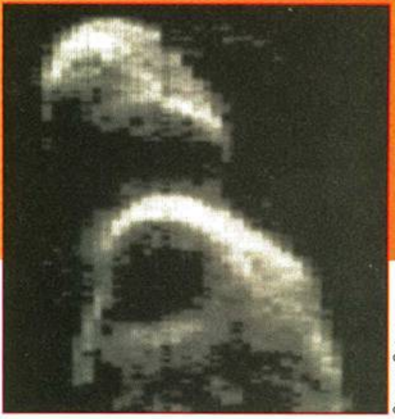


Radar reveals Toutatis as two asteroids stuck together (above). A photo from 1992 shows the asteroid's rapid motion (right).

Fast-moving Toutatis zips past Earth in early December and brightens to binocular visibility.

by Richard Talcott

A strangely shaped, dimly glowing object climbs out of the dawn and into view on these brisk December mornings. The lumpy, oblong piece of rock — asteroid 4179 Toutatis — measures less than 7 kilometers across. Rarely do objects this small come into view from Earth, but then objects rarely come this close to our planet.

Toutatis comes closest to Earth on November 29, when it lies just 5.3 million km away. But don't count on seeing it that night. The asteroid lies in nearly the same direction as the Sun, so it gets lost in the solar glare. In addition, most of its sunlit hemisphere faces away from Earth, causing the asteroid to glow feebly at 14th magnitude, about the same as Pluto.

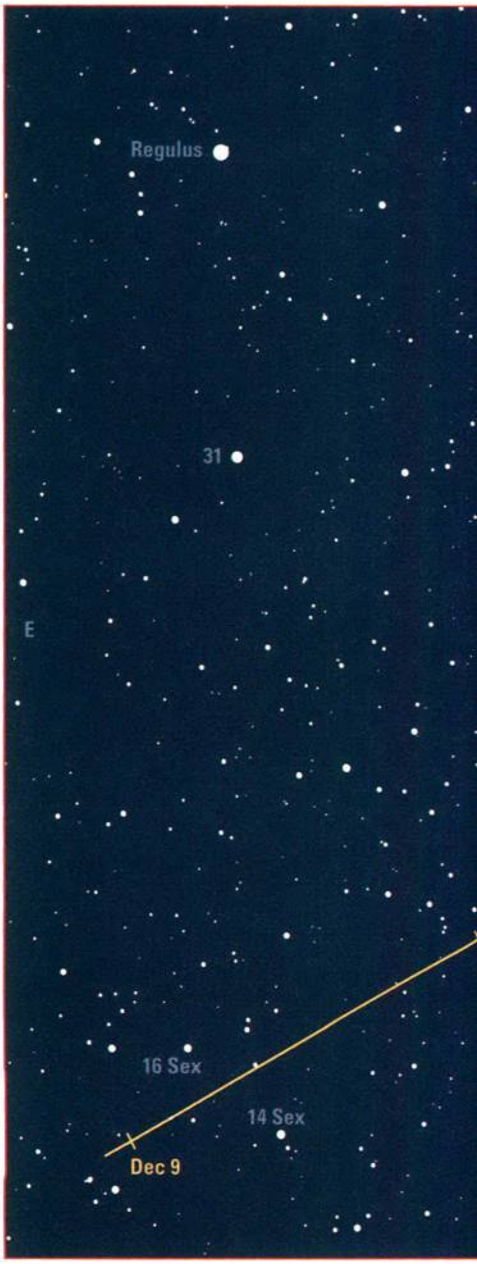
Luckily the situation changes rapidly for the better. As Toutatis speeds away from the Sun and Earth, it crosses Earth's orbit (ahead of us as we circle the Sun). This motion makes the asteroid shoot out of the morning twilight and appear high in the east well before the sky starts to brighten. This motion also means Toutatis turns more of its sunlit hemisphere in our direction, and it brightens to magnitude 10.5 by the end of December's first week.

The first good time to look for Toutatis is at the end of that week, when the waning crescent Moon has vacated the vicinity. Head out shortly after midnight and locate the two brightest objects in the east: blue-white Regulus and the slightly brighter, ruddy Mars. (The map at top right shows the view looking east at 1 a.m. local time.)

First-magnitude Regulus, the heart of Leo the Lion, serves as a convenient starting point in the search for Toutatis. On the morning of December 9, the asteroid lies about 6° due south of the star and 1° east of 14 Sextantis. The detailed finder chart at right shows Toutatis' position at 4 a.m. EST (3 a.m. CST, 2 a.m. MST, and 1 a.m. PST). It includes stars as faint as magnitude 11.3, so it approximates the view in a pair of 7x50 or 10x50 binoculars or a 2.4-inch telescope on a clear night from a dark site.

Toutatis moves quickly to the northwest during the next week, cutting through the southwestern corner of Leo. Although the chart should help you locate the asteroid whenever it's clear, perhaps your best chance will come on the morning of the 13th. It then lies just 0.2° west of the 3.5-magnitude star Omicron (o) Leonis. Once you center Omicron in your field of view, you should have little trouble spotting Toutatis. If you still can't tell which point of light it is, wait for an hour or two: That should be enough time for you to detect its motion against the background stars.

Although Toutatis appears as a single point of light, it really consists of two objects joined together. Radar measurements made four years ago when it last came close to Earth showed it to be a contact binary — essentially two huge boulders that collided softly and fused long ago. As you view Toutatis, it's worth pondering how many other boulders cross our orbit, and whether any of them have Earth's name on them. ☐



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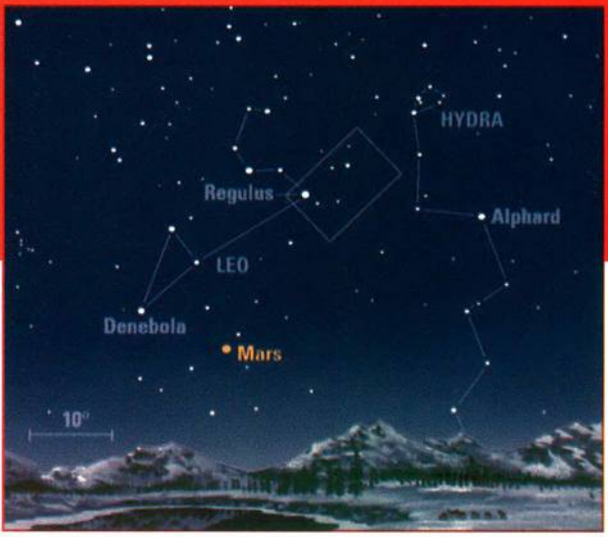
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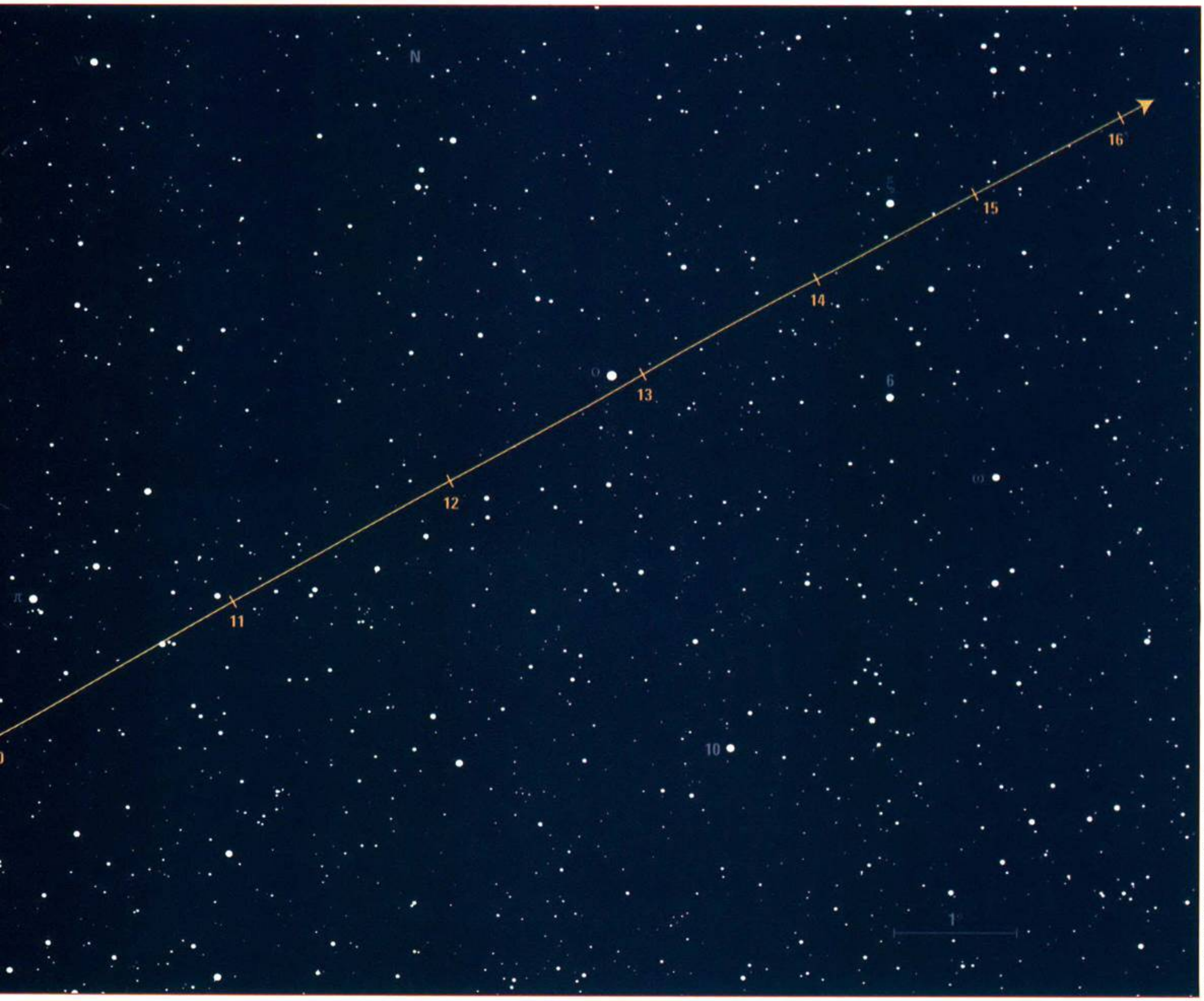
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1°

Both maps by ASTRONOMY: Elisabeth Rowan

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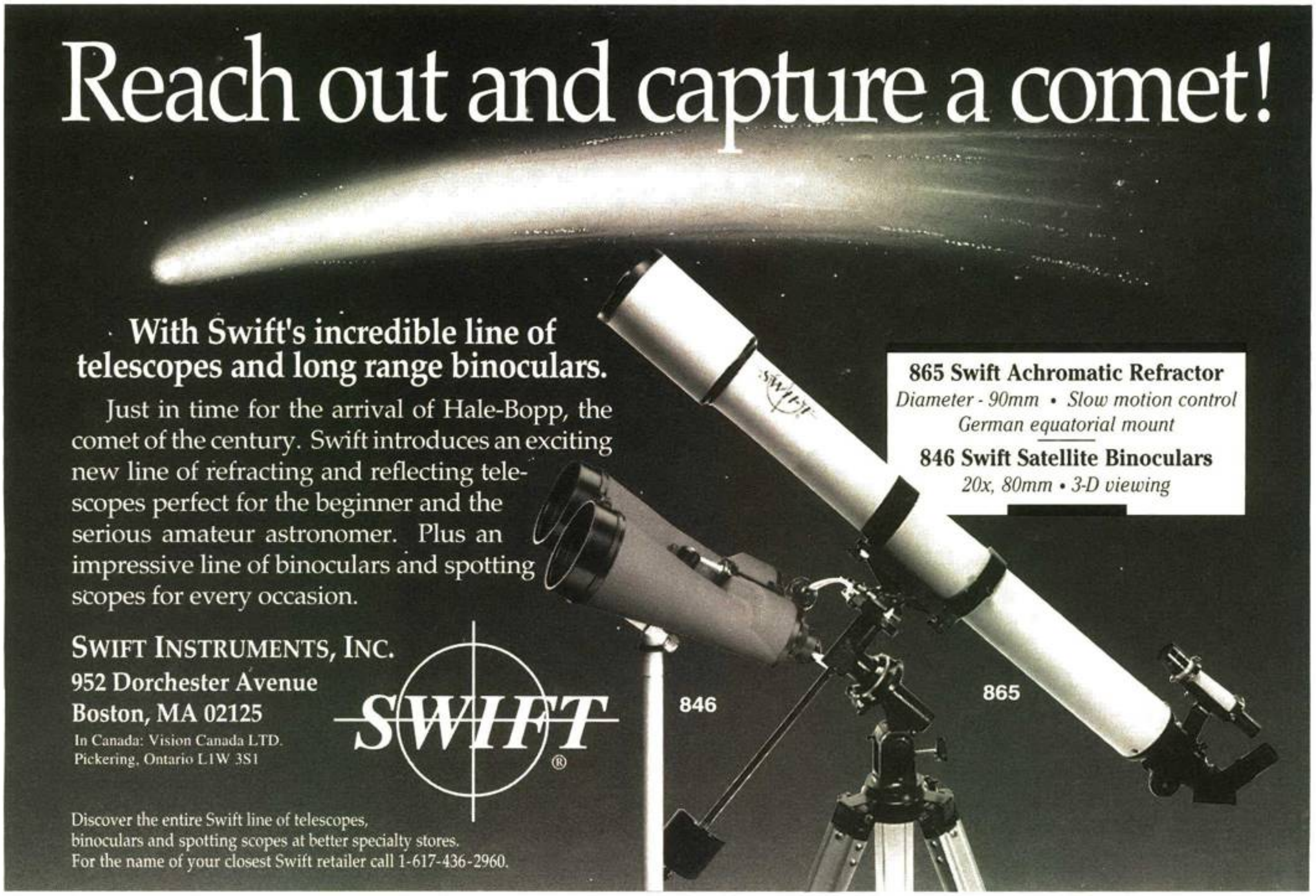

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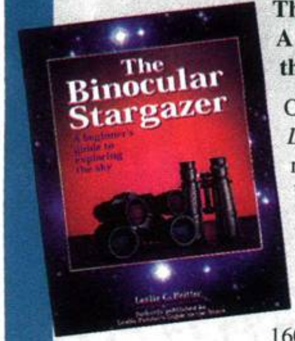

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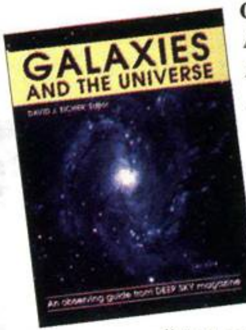

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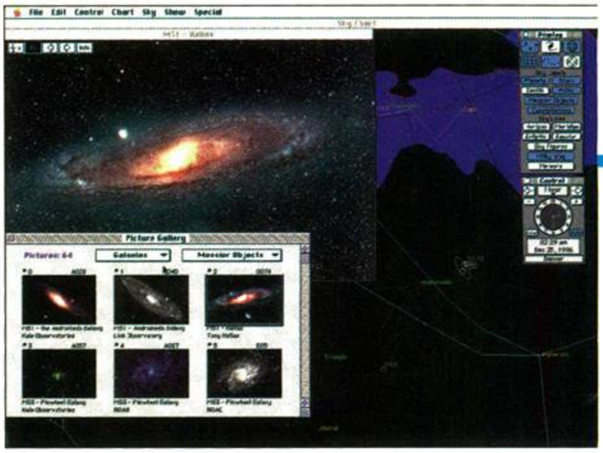
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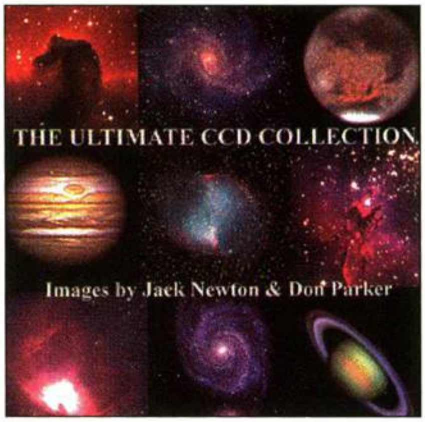
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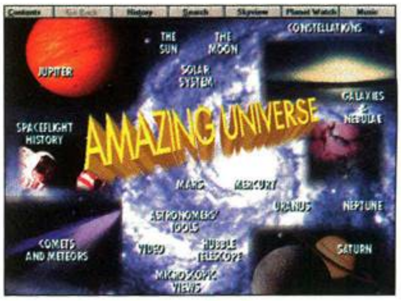
Jack Newton, 640 Cains Way, *RR6,* Sooke, B.C., Canada, VOS 1N0, (604) 642-6601, email anewton@uvic.ca, or Don Parker, 12911 Lerida Street, Coral Gables, FL 33156, (305) 666-8179, email 72317.3157@compuserve.com. Price: $29.95 U.S. Minimum requirements: 80386 computer with Windows 3.1, 4 MB RAM, 2.5 MB free hard disk space, CD-ROM drive, VGA display, and mouse.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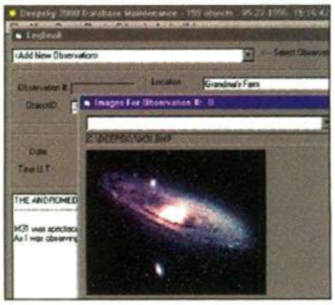
Hopkins Technology, 421 Hazel Lane, Hopkins, MN 55343, (612) 931-9376, fax (612) 931-9377, http://www.hoptechno.com. Price $39.95. Minimum requirements: 80386 computer with Windows 3.1, CD-ROM drive, VGA display (SVGA recommended), sound card, mouse.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Created for use with Windows 95, *DeepSky 2000* is a true 32-bit astronomy program written for observers. It features an observing planner, a sophisticated observer's logbook, and an image processing system that supports over 20 popular image formats including BMP, JPEG, LEAD, TIFF, and more. *DeepSky 2000 Lite* was written for Windows 3.1 and offers many of the same features as *DeepSky 2000* for Windows 95. Both products are available as shareware by download or purchase by mail or telephone.

DeepSky 2000, Steven S. Tuma, 912 N. Randall Avenue, Janesville, WI 53545, (608) 752-8366, e-mail stuma@inwave.com, http://www.inwave.com/stuma/ds2000.html. Price: $35 (DeepSky 2000) on diskettes, $20 by download; $25 (DeepSky 2000 Lite) on diskettes, $15 by download. Minimum requirements: 80386 computer with Windows 3.1, 8 MB RAM, 10 MB free hard disk space, VGA display, and mouse.

Product information is as provided by the developer. Software developers may send new programs and upgrades to AstroBytes, ASTRONOMY, *P.O. Box 1612, Waukesha, WI 53187-1612 or e-mail bytes@astronomy.com. Check out* ASTRONOMY*'s home page at http://www.kalmbach.com/astro/astronomy.html*

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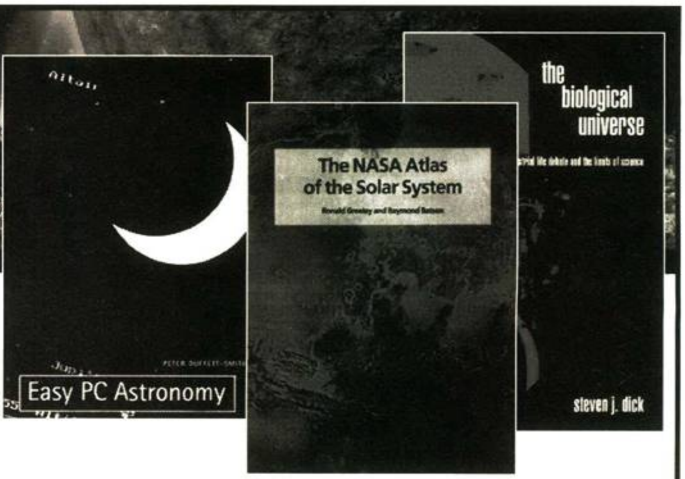

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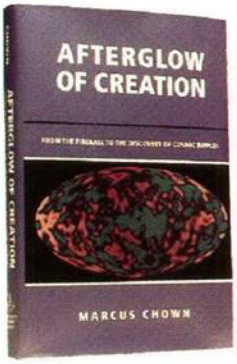
Raisin Cakes, Microwaves, and The Universe

by Anne Fitzgerald

Afterglow of Creation: From the Fireball to the Discovery of Cosmic Ripples

Marcus Chown, 222 pages, University Science Books, Sausalito, Calif.,1996; ISBN 0-935702-40-7, hardcover, $28.50.



What do raisin cakes and microwaves have to do with the universe? Marcus Chown answers this question and many more in *Afterglow of Creation*. Chown, a well-known science writer, has written for the publications *New Scientist* and *The Guardian*, and he has also written two science fiction novels and a children's book.

In *Afterglow of Creation*, Chown takes the reader on a journey from the time just before the Big Bang to the year 1992, when the Cosmic Background Explorer satellite (COBE) confirmed that radiation from the Big Bang was still with us in the form of microwaves. Chown packs an incredible amount of information into a 222-page book. His descriptions make abstract concepts clear, like the familiar analogy of a rising cake with raisins to describe the relationship between the galaxies and the expanding universe.

Photographs and interview excerpts demonstrate the hard work and commitment of scientists by taking the reader into labs and lecture halls, and out into the field. As one reads the book, one gets a sense of the dedication involved in the 20-year effort to isolate the microwave radiation left by the Big Bang. One follows the careers of scientists who built early radio antennas and went on to design and test COBE.

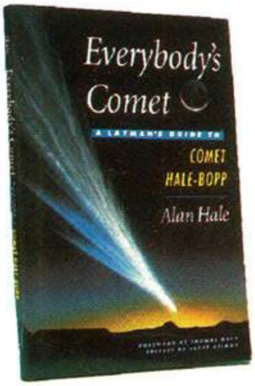
When COBE finally went into space, it rose above all of the earthly radio noise that prevented scientists from isolating cosmic microwaves. In 1992, scientists discovered variations in temperature (cosmic "ripples" in the microwave background) that were the remnants of the births of the galaxies. Chown gives a balanced account of the media blitz that followed. The words of the scientists give us a sense of their frustrations, hurt feelings, and misunderstandings as well as their relief, pride, and elation. Chown writes, "COBE had seen to the very heart of things. It had stripped away all of the bewildering complexity of the Universe. And there at the beginning of time was breathtaking simplicity — more beautiful than anyone had dared imagine."

Chown's book shows us that we are unique witnesses to the beginning of the universe. Books like *Afterglow of Creation* keep the story of the universe and the hard work of human discovery alive.

Anne Fitzgerald is an amateur astronomer, insurance underwriter, and freelance writer.

Everybody's Comet: A Layman's Guide to Comet Hale-Bopp

Alan Hale, 162 pages, High-Lonesome Books, Silver City, N.M., 1996; ISBN 0-944383-38-6, softcover, $12.95.



Comet Hale-Bopp codiscoverer Alan Hale weighs in with this conversational account of the discovery of his comet and what to expect when it graces our skies next spring. Hale tells the reader where, when, and what to look for. He also lays out what a comet is and what Hale-Bopp might mean for cometary studies. Color photos bound into the book's center show great comets of the past and artists' renderings of what Comet Hale-Bopp might look like next spring. As a diversion, the afterword is an essay on what Hale-Bopp's discovery meant to its codiscoverer. Hale also speaks his mind on issues that shape scientific literacy. If you can't find *Everybody's Comet* in your local bookstore, you can order it directly from the publisher at 1-800-380-7323. Mastercard and Visa are accepted. —*John Shibley*

Other Books

The Cambridge Star Atlas, Second Edition

Wil Tirion, 90 pages, Cambridge University Press, New York, N.Y., 1996; ISBN 0-521-56098-5, hardcover, $19.95.

This second edition to *The Cambridge Star Atlas* adds a description about the Moon with a map and an explanation of lunar phases. The binocular/low-power telescopic map plots the location of major mare and 249 craters. The star map section features 24 monthly constellation maps for both hemispheres, followed by 20 detailed color charts and data tables for each object plotted. This edition separates keys for the detailed sky maps from the monthly constellation maps. This is an improvement over the first edition, in which the keys confusingly overlaid the monthlies. A final section plots the distribution of constellations, open clusters, globular clusters, planetary nebulae, diffuse nebulae, and galaxies on separate, all-sky maps. This volume is good for use as a general reference and desk atlas.

Cambridge Pocket Star Atlas

John Cox, 48 pages, Cambridge University Press, New York, N.Y., 1996; ISBN 0-521-58992-4, softcover, $6.95.

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World-Building: A Writer's Guide to Constructing Star Systems and Life-Supporting Planets

Stephen L. Gillett, 198 pages, Writer's Digest Books, Cincinnati, Ohio, 1996; ISBN 0-89879-707-1, hardcover, $16.99.

For all you aspiring science fiction writers out there, this book will help make your stories come alive. Geologist Stephen L. Gillett knows that not every planet can support life, so he tells the reader how to conjure up realistic life-bearing planets and planetary systems based on current scientific knowledge. Frequently citing famous sci-fi stories, Gillett explains tidal effects, volcanism, the greenhouse effect, and so on. The final chapter speculates on possible life-bearing planets very different from Earth. For non-sci fi buffs, this book serves as a primer for planetary geology and atmospheric sciences. *World Building* is part of the Science Fiction Writing Series, edited by Ben Bova. If you like this book, you will probably also enjoy *Aliens and Alien Societies: A Writer's Guide to Creating Extraterrestrial Life-Forms*, by Stanley Schmidt (Writer's Digest Books, 1995, ISBN 0-89879-706-3). ☐

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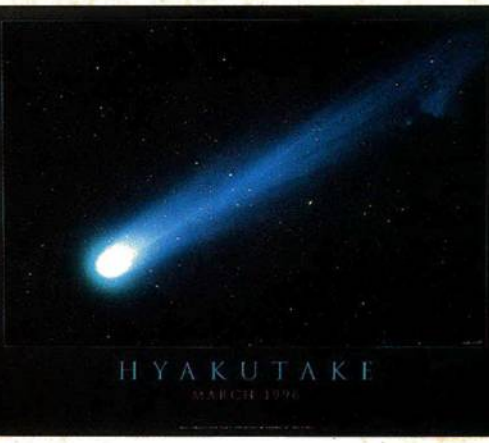

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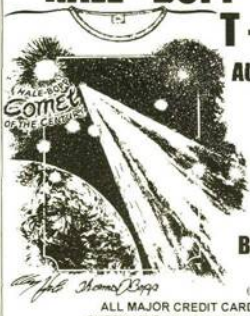

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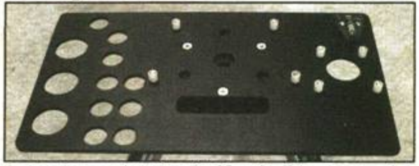

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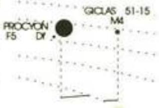

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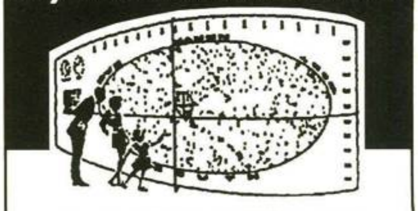

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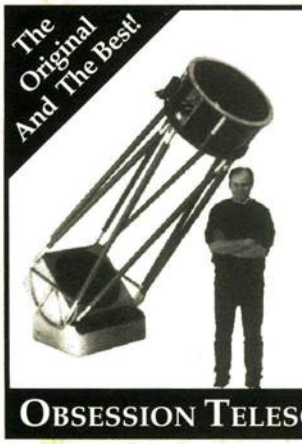

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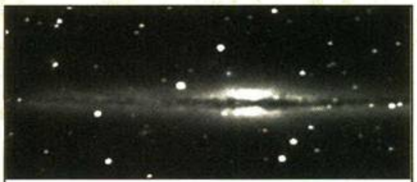

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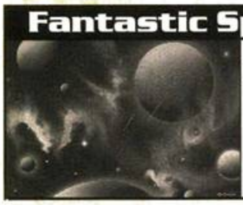

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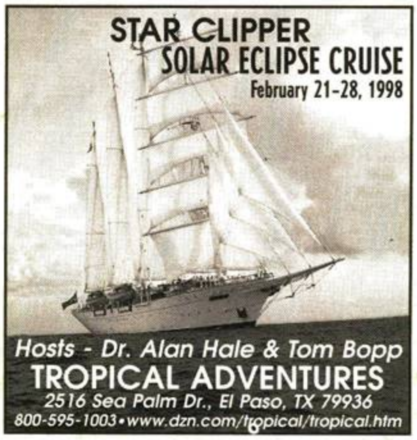

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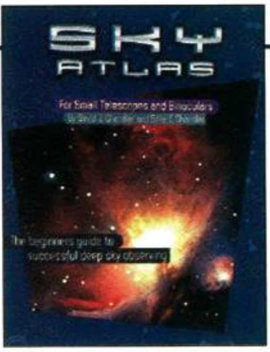
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Sky Atlas for Small Telescope and Binoculars is for beginning observers who want to embark upon deep-sky observing with starter instruments. At its heart, the atlas presents eight views of the sky, from north to south polar regions. Each chart shows stars to magnitude 6, constellation outlines, and nearly 200 deep-sky objects visible in smaller telescopes. The general shape and extent of our Milky Way is also plotted. Opposite each chart are object tables broken out by constellation. Bookending the chart section is general advice on how to get started in observing the sky and a resource list that recommends useful books, periodicals, and software. *Sky Atlas* comes in softcover and runs 22 pages.

David Chandler Company, P.O. Box 309, La Verne, CA 91750; (800) 516-9756; (909) 988-5678; fax, (909) 988-5618; e-mail, dschandler@frumble.claremont.edu; http://www.csz.com/dschandler. Sky Atlas for Small Telescopes and Binoculars: $12.95, plus shipping — $2 domestic, $4 foreign.

Atmospheric Phenomena Detector

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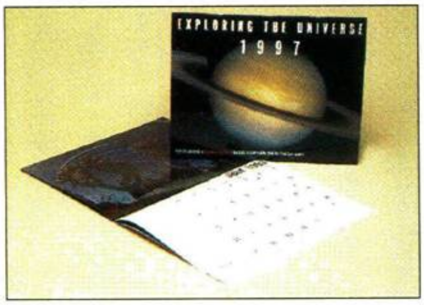


1997 ASTRONOMY Calendar

ASTRONOMY magazine and the Planetary Society team up to publish *Exploring the Universe 1997*, a 12-month wall calendar. Editors culled through 1996's best astrophotography and space art to compile anchor illustrations. Monthly narratives present a full explanation of each illustration, plus a thumbnail on where to look for the planets. Daily information includes notable anniversaries in astronomy and space science history, plus mention of many sky phenomena. *Exploring the Universe* measures 13½" by 21" when opened up.

Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-0986; (800) 533-6644; (414) 796-8776; fax, (414) 796-1615. Exploring the Universe 1997, stock #68090: $12.95 plus shipping.

Astronomical Postcards

Austrian astrophotographer and frequent ASTRONOMY contributor Gerald Rhemann has put together a set of four postcards that represent the best of his astrophotography. This set includes the Rosette Nebula in Monoceros, the North America Nebula in Cygnus, the Orion Nebula, and the Pinwheel galaxy in Triangulum. Each postcard measures 4⅛ x 5¾ inches, and has a glossy face with room on the reverse side for a message and address.

Astronomical Working Group Salzkammergut, Sachsenstrasse 2, A-4863, Seewalchen, Austria; phone, 011-43-07662-8297. Astronomical Postcards: $6 (includes postage).

Blinking Hazard Lights

These blinking light-emitting diodes (LEDs) snap onto the contacts of any 9-volt battery. Place them near tables, tripod legs, tent ropes, protruding counterweight shafts, or anything else that people might trip over in the dark. The red LEDs won't harm night vision, and run up to 100 hours on one battery. Each unitÆs lamp and control chip is heat-wrapped in molded plastic to resist moisture and to make it durable. The tough lights can take being stepped on or even run over with a car. Each light comes shipped in a resealable zip-lock bag.

Tech 2000, 3349 SR 99 S, Monroeville, OH 44847; (419) 465-2997. Blinking LED Beacon: $5 each, 4 for $16, plus $ 3 shipping and handling.

New Products presents announcements issued by manufacturers. ASTRONOMY assumes no responsibility for the product information supplied. Prices are suggested retail. Suppliers should send announcements and color photographs to the attention of John Shibley, P.O. Box 1612, Waukesha, WI 53187, or newprod@astronomy.com.

Precision CCD Filters

Optometrics makes various types of filters to exacting standards for science and industry. Now they offer four filters specifically designed for CCD imaging: H-alpha (656.3 nanometers), Oxygen-3 (500.1 nm), Sulfur-2 (672.5 nm), and visible band (400 - 700 nm). Each 1¼-inch, threaded filter can be purchased separately or as a set. Filters come with a manual that outlines which features should be revealed in a variety of deep-sky targets.

Optometrics USA, Inc., Stony Brook Industrial Park, 6 Nemco Way, Ayer, MA 01432; (508) 772-1700; fax, (508) 772-0017; e-mail, opto@optometrics.com; Web page, http://www.optometrics. com/. 1 ¼-inch threaded CCD filters: $120 each, $399 for the set.

Page-A-Day, Desktop Astronomical Calendar

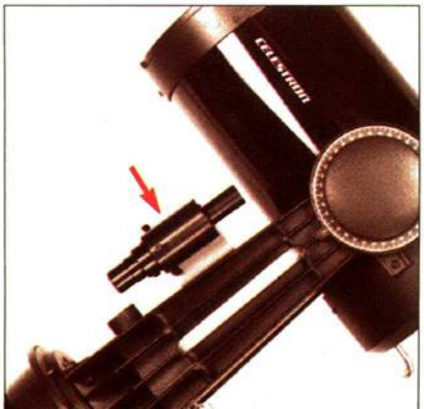
Former ASTRONOMY almanac columnist Fred Schaaf compiled photos and wrote the text for this page-a-day calendar. Each day features a photo taken by interplanetary spacecraft, Apollo astronauts, or the Hubble Space Telescope. Schaaf presents an interesting scientific and historical perspective in a narrative that runs under the image. The page also mentions if anything notable happens in the sky for that particular day. A small note area under the date lets you jot down down important appointments. Tear off one sheet from the pad to advance to another date. The entire pad sits in a black, plastic holder.

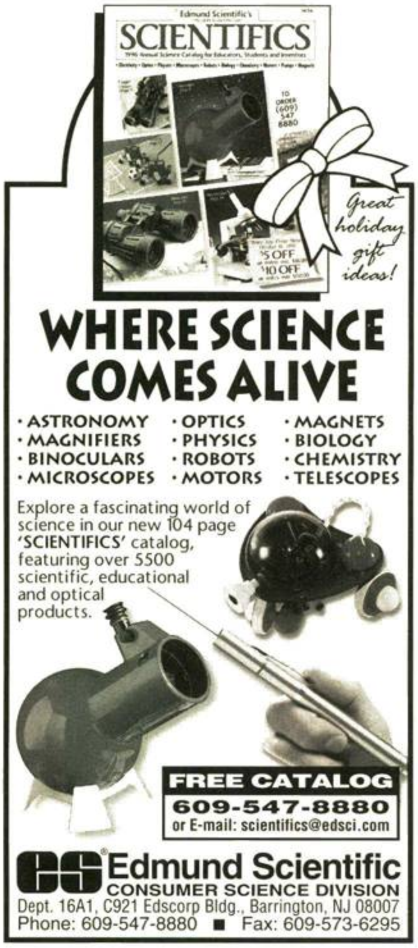
Accord Publishing Company, 1407 Larimer Square, Suite 206, Denver, CO 80202; (303) 595-3839. 1997 Space Calendar: $10.95 each, plus $3 shipping & handling.

Polar Alignment Scope for Equatorial Telescopes

This 1-power finder scope attaches to an equatorial mount to aid in finding the north (or south) celestial pole, a necessity for long-exposure astrophotography. Reference stars inscribed on the finder's reticle eyepiece pinpoint the pole's location. You adjust the reticle for time of year and maneuver the telescope mount until everything lines up in the eyepiece. JMI also offers a reticle illuminator with an energy-saving auto-shutoff feature. Polar finders fit Meade and Celestron SCTs, Meade German equatorial mounts, and JMI's NGT telescope mounts. When ordering, specify which celestial pole reticle you'll need.

Jim's Mobile Inc., 810 Quail St., Unit E, Lakewood CO 80215; (800) 247-0304; fax, (303) 233-5359. The EZAlign Polar Alignment Scope: $199.95, plus Shipping. Red LED with auto shutoff: $19.95, plus shipping.





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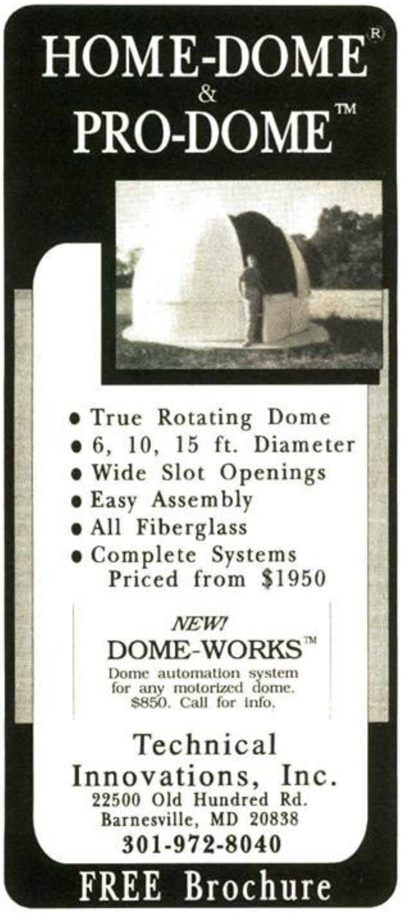

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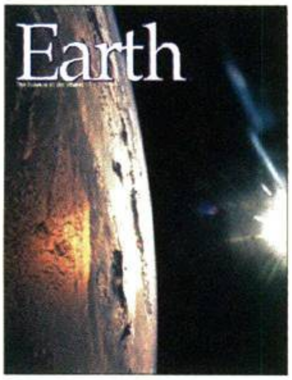

Looking at Earth

With its December issue, *Earth* is five years old. To celebrate we are offering a special collection of essays on the topic LOOKING AT EARTH, written by distinguished authors. They will discuss what people knew about Earth 1,000 years ago, what our great achievements in earth science have been since then and what critical questions remain.

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- **David Lindberg,** historian of science, University of Wisconsin -Madison
- **Eldridge Moores,** president of the Geological Society of America
- **Michael Wysession,** geophysicist at Washington University in St. Louis
- **Tom Wigley,** senior scientist at the National Center for Atmospheric Research
- **Daniel Orange** from the Monterey Bay Aquarium Research Institute

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MEETINGS EVENTS

Cosmic Voyage, Langley Theater, Smithsonian Institution's National Air and Space Museum, Sixth Street and Independence Avenue, S.W., Washington, DC. IMAX film featuring scientific simulations based on data drawn from National Science Foundation cosmology research.

November 22
Life in the Solar System Symposium, George Washington University campus, downtown Washington, DC. Sponsored by the Space Policy Institute with the Planetary Society and the National Space Society. Contact cistp@gwis2.circ.gwu.edu with message titled "Mars Symposium."

January 10-11
Seventh All-India Amateur Astronomers' Meet, Nehru Planetarium, New Delhi, India. Sponsored by the Amateur Astronomer Association of Delhi. Contact Amitabh Pandey, Nehru Planetarium, Teen Murti, New Delhi 110011, India, telephone, 91-11-3014504 (4:00-12:00 UT), e-mail, aaadel@poboxes.com.

February 3-9
Winter Star Party, Camp Wesumkee, Florida Keys. Sponsored by the Southern Cross Astronomical Society. Contact Bob Grant, 5401 S.W. 110 Ave., Miami, FL 33165, (305) 595-8778, bginsofl@aol.com.

February 6-9
The Orange Blossom Special Star Party, Hickory Hill Observing Complex, near Brooksville, Florida. Sponsored by the St. Petersburg Astronony Club. Contact Dennis and Ellen Farr, 8811 West Broad Street, Tampa, FL 33615 (813) 884-9111.

February 15
Wagman Winterfest, Nicholas E. Wagman Observatory, Mahaffey Road, Deer Lakes Regional Park, Russellton, Pennsylvania. Free. Contact (412) 224-2510, pzapadka@fyi.net, http://trfn.clpgh.org/orgs/aaap. □

Please submit club announcements four months in advance to Meetings and Events, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612, or to tconley@astronomy.com.

RESOURCES PHOTOFACTS

To Kill a Galaxy (page 36)

Alchemy of the Heavens, by Ken Croswell, (Anchor Books, 1995). A book about the Milky Way Galaxy, chapter 15 discusses the Galaxy's satellite empire.

Galaxies, by Timothy Ferris, (Stewart, Tabori and Chang, 1982). This classic book contains beautiful galaxy photographs, including those of dwarf galaxies.

The Lone Astronomer (page 42)

Asimov's Biographical Encyclopedia of Science and Technology, by Isaac Asimov, (Doubleday and Company, 1982). Biographies of scientists from ancient times to the present.

WIYN Is a Winner (page 56)

http://www.noao.edu/wiyn/wiynimages.html. The WIYN Telescope home page contains WIYN images, along with information about the images and the telescope.

Piece by Piece Astrophotography (page 84)

Introduction to Astronomical Image Processing, by Richard Berry, (Willmann-Bell, 1991). Walks through the basics of electronic image processing.

Exploring Sinus Medii (page 90)

Atlas of the Moon, 2nd edition, by Antonin Rükl, (Kalmbach Books, 1996). An ideal lunar atlas for work at the eyepiece.

The Moon: An Observing Guide for Backyard Telescopes, by Michael Kitt, (Kalmbach Books, 1991). Presents regional tours of the Moon. □

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p. 49, inset: Tony and Daphne Hallas, M33, 12 ½-inch f/7 Newtonian, two 45-minute exposures sandwiched and printed on Vericolor Print Film. Taken from Cima Dome, California; **p. 64:** Orion rising through the trees, Fred Hafeli, 50mm lens at f/4, Ektachrome 400, 5 minutes; **p. 69, top:** M42 and Orion's belt stars, John Shibley, 70mm lens at f/4.5, 3M 1000 slide film, 25 minutes; **p. 69, bottom:** M42 close-up, Mike Sisk, 24-inch Cassegrain telescope; **p. 71:** Horsehead Nebula region, 6-inch f/7.5 refractor, hypered Fujicolor Super HG400 print film, 50 minutes; **p. 72:** Geminid meteors, Steve Edberg, 35mm lens at f/2.8, Ektachrome 400 film, 20 minutes.

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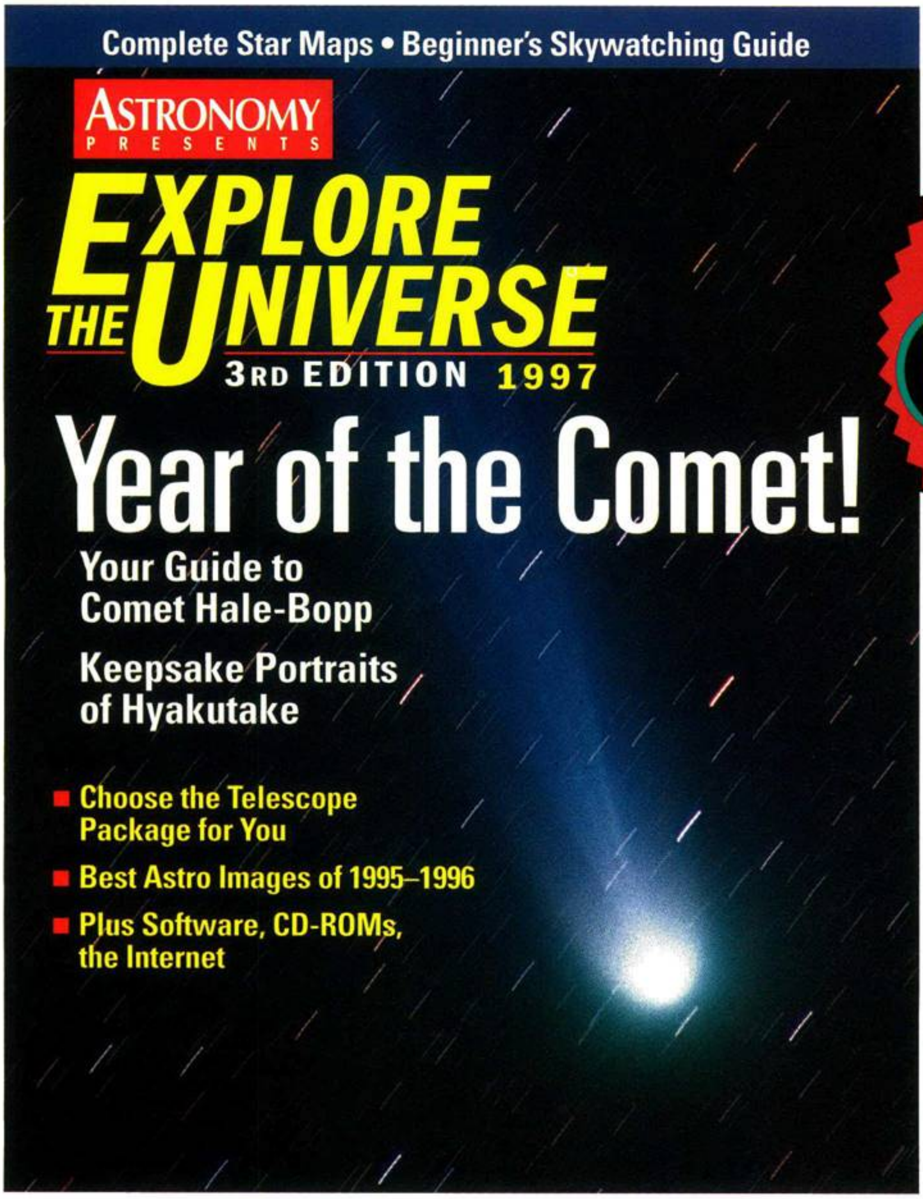

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Books and Periodicals Wanted

Book: HOW TO BUILD YOUR OWN OBSERVATORY. Steve Traudt, 412 Main, Grand Junction, CO 81501. (970) 245-6700. synvis@gj.net

Miscellaneous For Sale

Canadian Skywatcher's Trivia Calendar. E-mail: shadick@sask.usask.ca Orders: (800) 360-8826 (Canada).

E=MC^2. SASE: Quantum Enterprises, 3720 West Maunaloa, Phoenix, AZ 85023.

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Tony and Daphne Hallas

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Of Shooting Stars and Faint Fuzzies

This hobby of astronomy has something for everybody. One can sit back on the grass and with the unaided eye watch satellites and meteors skim above Earth's surface.

Other hardcore skywatchers case out the far reaches of our universe, looking for "faint fuzzy" galaxies. Such observers are always up for new challenges, and in the Hickson catalog, they've found one.

Go Deep, Go Fuzzy. In the early 1980s Canadian astronomer Paul Hickson set out to photograph some tiny galaxy groups that showed up on *Palomar Sky Survey* plates, using the Canada-France-Hawaii Telescope on Mauna Kea.

A book of his results, the *Atlas of Compact Groups of Galaxies* (Gordon Breach Science Publishers, ISBN 2-88449-116-3) presents images and data on 100 clusters he studied. The list has been grist for diehard deep-sky observers for the last year or so.

One such observer, Ray Cash of the San Francisco Sidewalk Astronomers, spotted no fewer than 13 of the faint clusters with his 17½-inch reflector during one evening last September.

He mentions that many of the enigmatic galaxies were visible only with averted vision, and even then were easy to confuse with 17th-magnitude stars. Other Hickson members proved simple targets in his

The Bubble Nebula (NGC 7635) and M52 in Cassiopeia
George Greaney
(6-inch f/7 refractor, hypered Fuji SHG400 120 format, composite of two 60-minute exposures)

Halo around the Full Moon
Frank Zullo
(20mm lens at f/8, Fuji Provia 400 film, 2-minute exposure)

scope, even to the point of showing subtle structure.

Incidentally, Hickson galaxies fall into a range of magnitude 14 to 15.

Enigmatic Perseids? Perhaps more intriguing than tales of Hickson galaxy jaunts is initial word of a spike in last August's Perseid meteor activity.

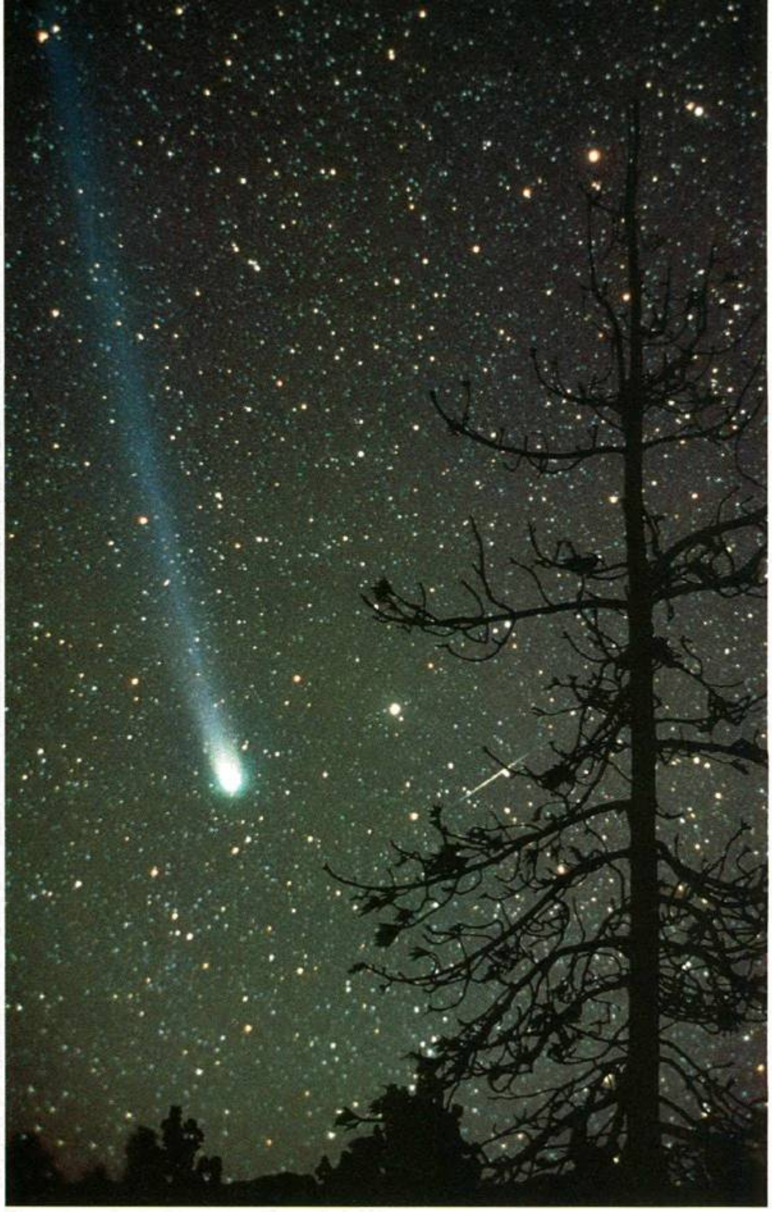
From his observing site near Samobor, Croatia, Ivica Skokic logged an average rate of 220 meteors per hour centered around 20h UT (4 p.m. EDT) on August 11. By 22h30m UT, Skokic noted a slight drop-off to 170 an hour before clouds interfered with observations.

Scottish skywatcher Gary Peterson says a Perseid that "left an imprint when I closed my eyes" sounded "a bit like a soprano mosquito just at the edge of your hearing." No mosquitoes, he assures us, were nearby at the time.

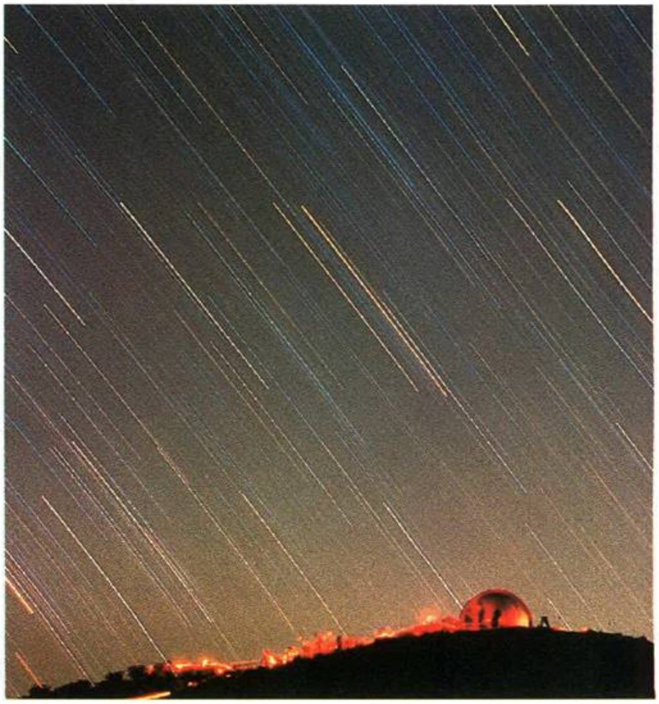
North American meteor watchers weren't necessarily deprived of a show, with a reported hourly average of between 80 and 100 meteors an hour.

Texas watchers Louis Binder and Loyd Overcash saw 100-plus between 8h and 9h UT on the morning of August 12. And Martin Gaskell of Lincoln, Nebraska, mentions that his observation of mean meteor brightness runs almost two magnitudes brighter than the historical average. □

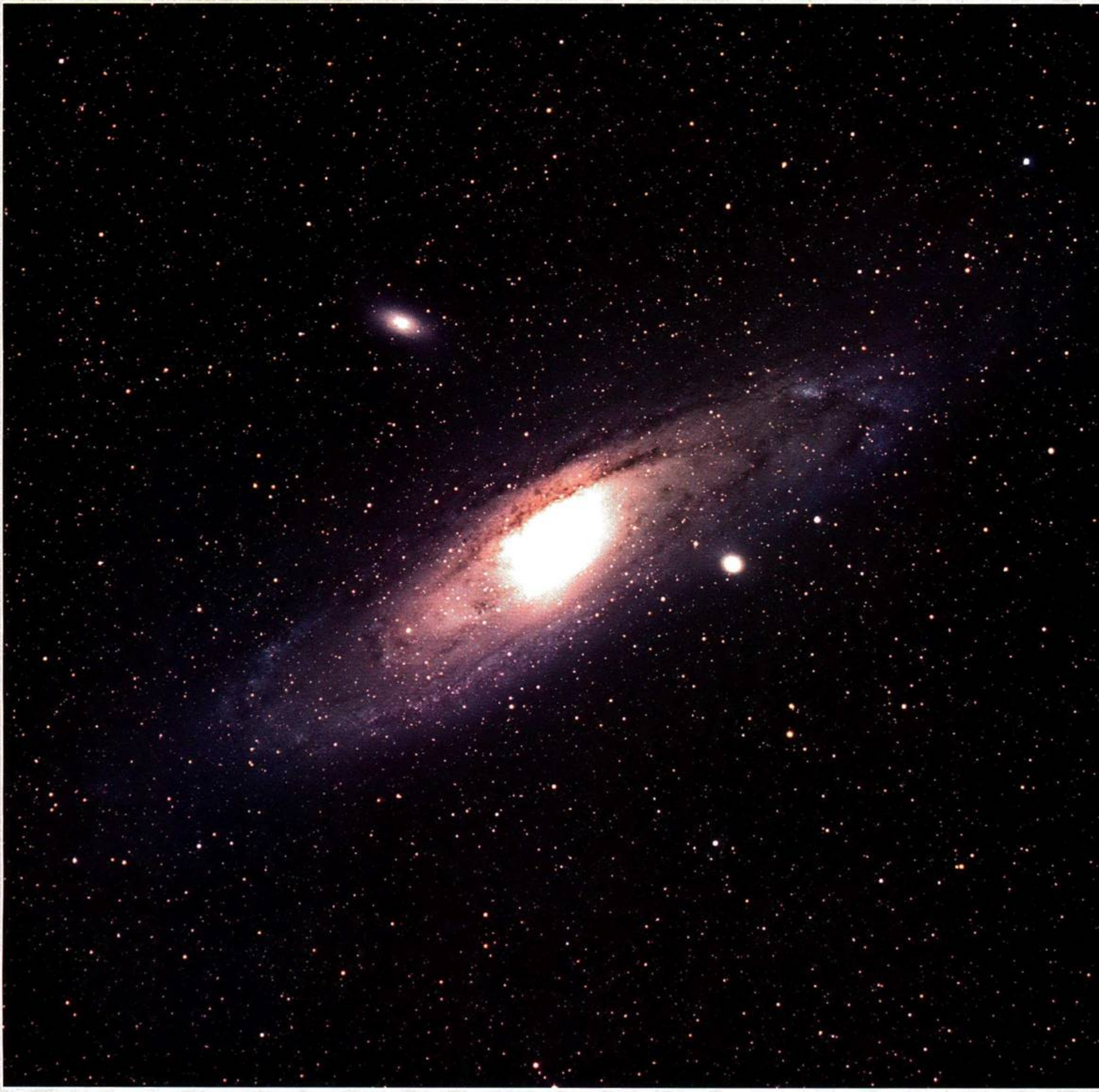
ASTRONOMY wants to share your observations of the sky with our readers. Send reports, sketches, photographs, and disks to John Shibley, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612. Please label each photo with photo data, name, address, and social security number. You may send written reports and images via the Internet to: rreports@astronomy.com.



Comet Hyakutake
Dennis Mammana
(50mm lens at f/2, Ektachrome 1600 film, 4-minute exposure)

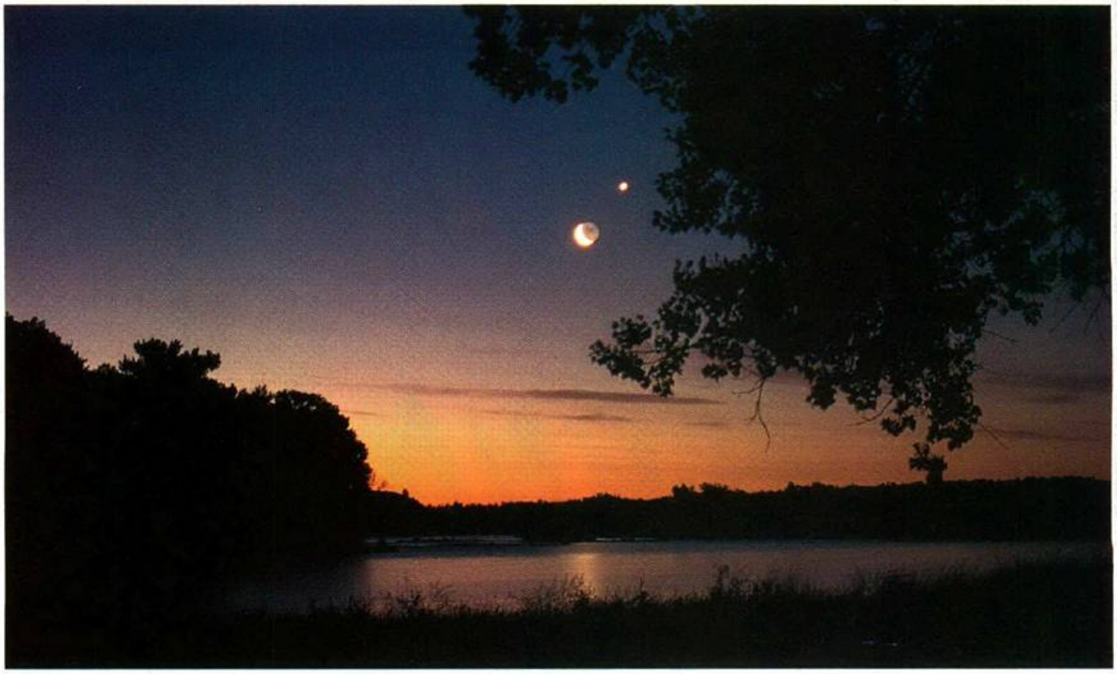


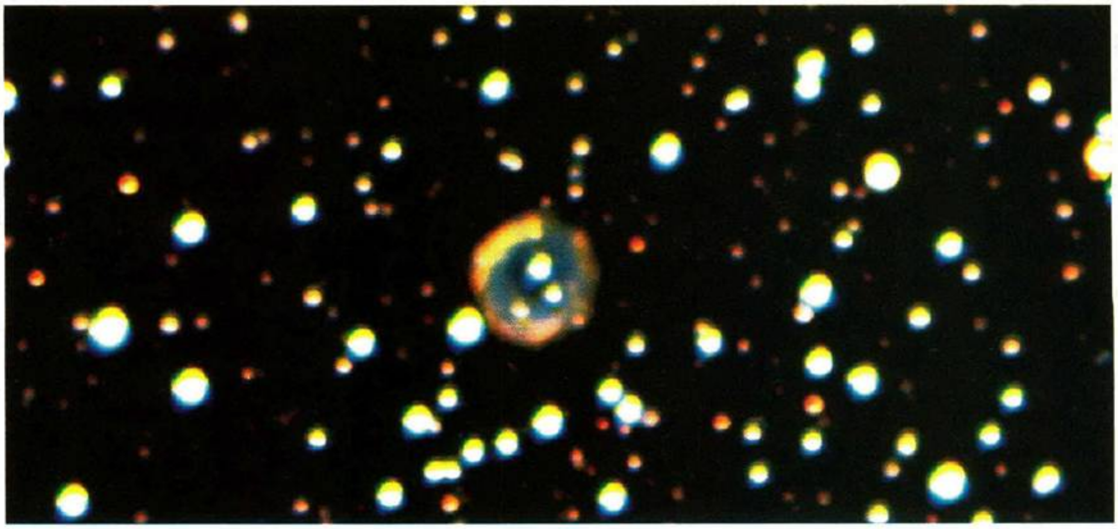
The Vega-Bray Observatory under Star Trails
Frank Zullo
(55mm lens at f/2.8, Kodak EPL 400 film, 20-minute exposure)



Great Spiral Galaxy M31 in Andromeda
George Greaney
(6-inch f/7 refractor, Kodak PPF 120 film,
composite of two 45-minute exposures)

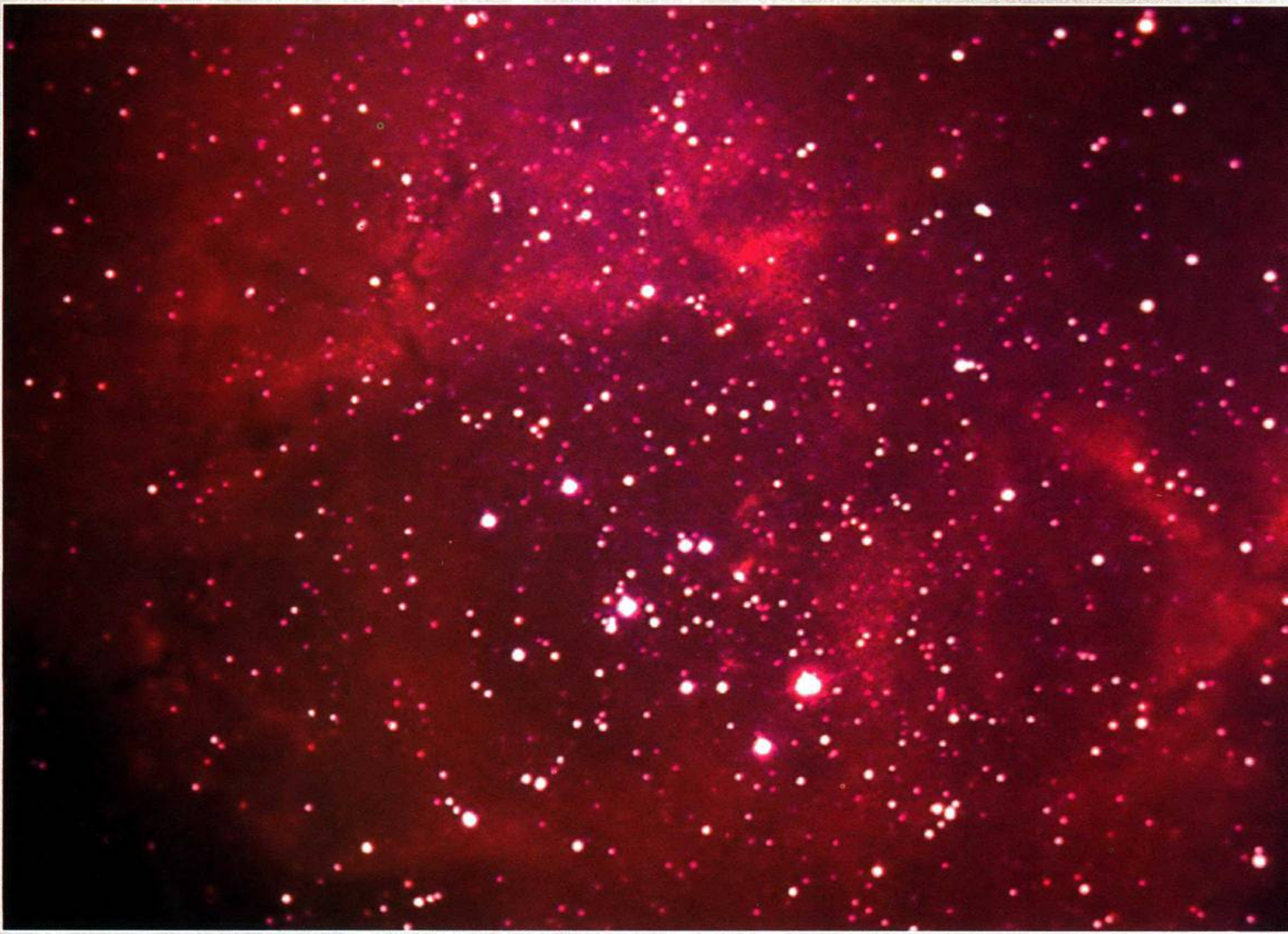
Crescent Moon's conjunction with Venus, July 12, 1996
John McNed
(70mm lens at f/3.5, Fujichrome 1600 film, 20-second exposure)



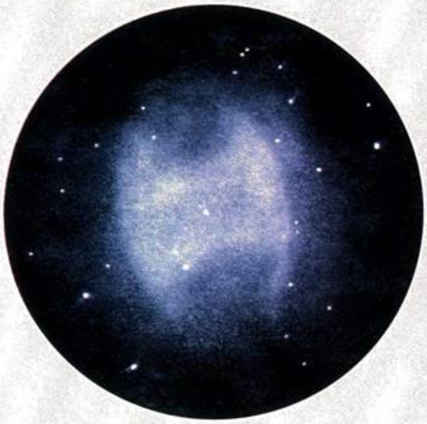


Planetary Nebula NGC 2438 Nested in M46
James McGaha and Tim Hunter
(24-inch f/5 reflector, Spectrasource HPC1 CCD camera, composite shot through blue [5 minutes], violet [2 minutes] and red [1 minute] filters)

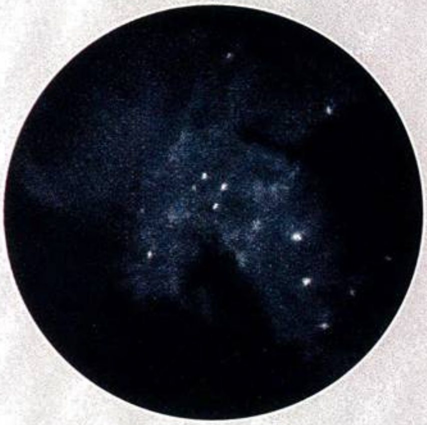
Open Cluster M7 in Scorpius
Lee C. Coombs
(10-inch f/5 reflector, Scotchchrome 400 pushed to ISO 800, 5-minute exposure)



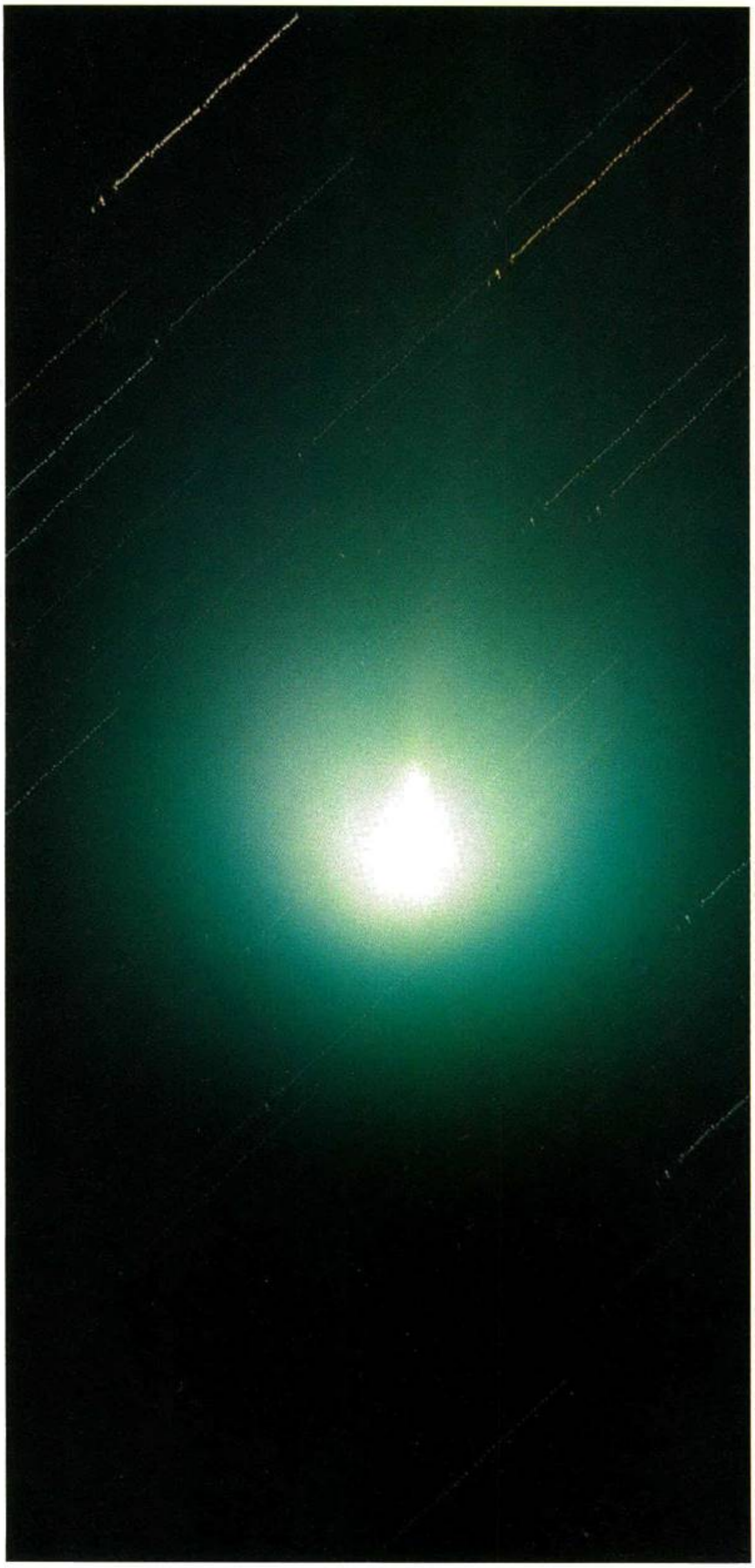
The Rosette Nebula in Monoceros
John Chumack
(16-inch f/4.5 reflector, Ektar 1000 film, 30-minute exposure)



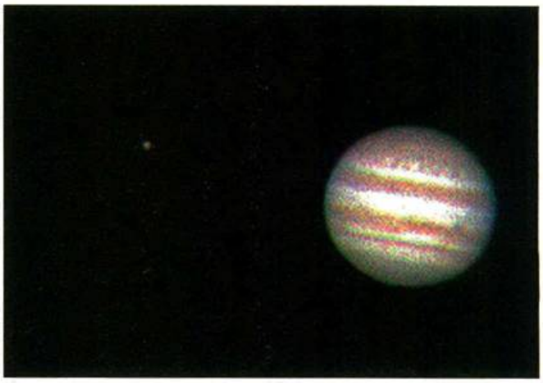
The Dumbbell Nebula, M27, in Vulpecula
Todd Hargis
(13.1-inch f/4.5, 104x with a Meade no. 911 nebular filter)



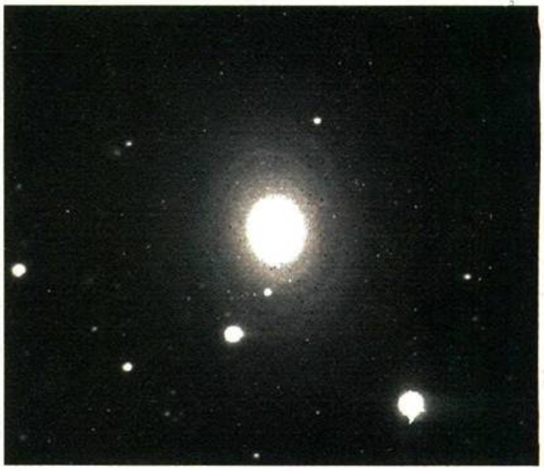
The Great Orion Nebula, M42
John Deitz
(17½-inch f/4.5, 200x with a Lumicon UHC filter)



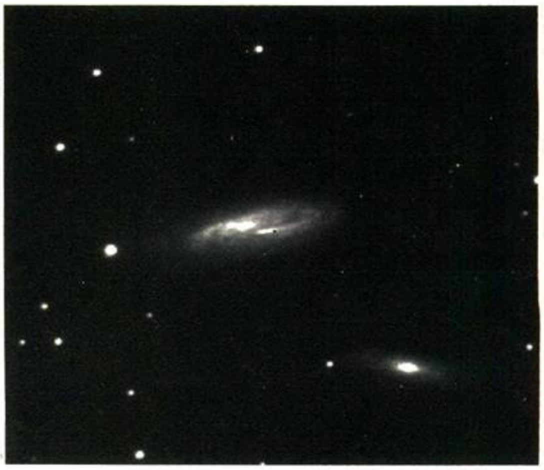
Comet Hyakutake Close-up, March 25, 1996
Thomas Alleger
(8-inch f/5 reflector, Fujicolor 400 HD film, 15-minute exposure)



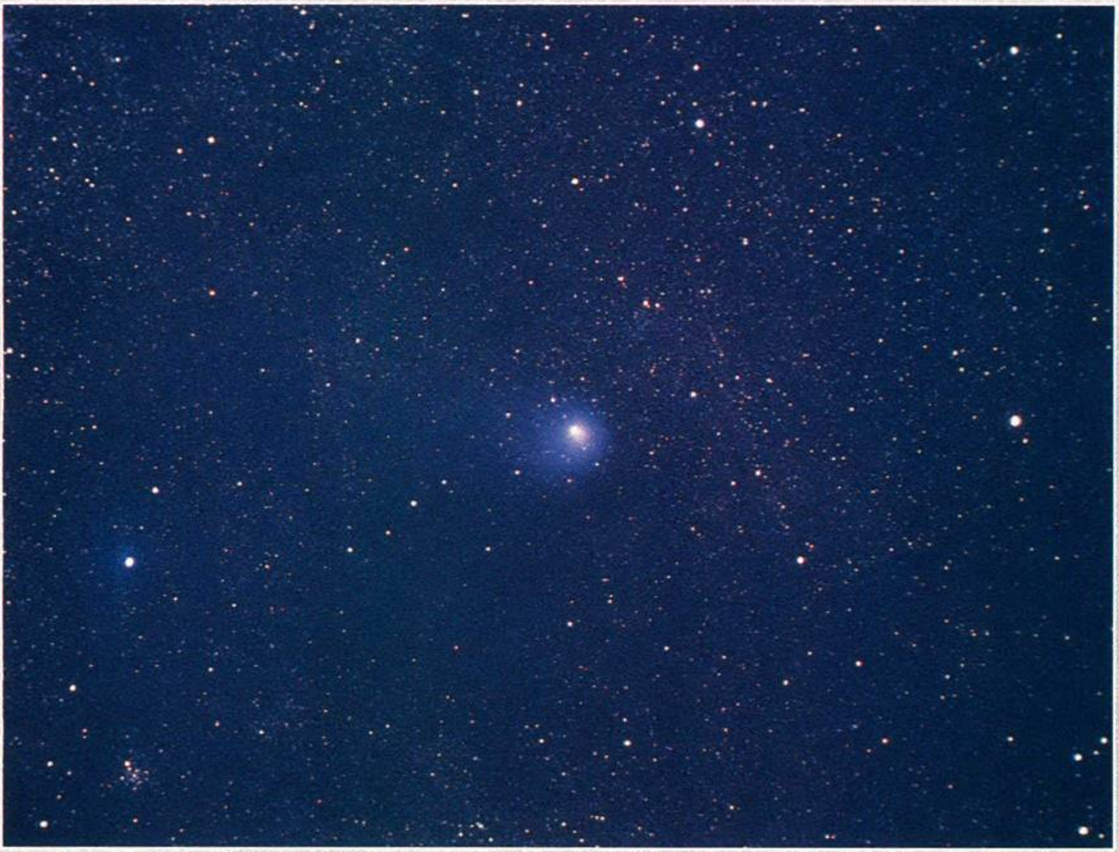
Jupiter and Ganymede, July 28, 1996
Gregory Terrance
(8-inch f/5 reflector, Celestron Pixel 255 CCD camera)



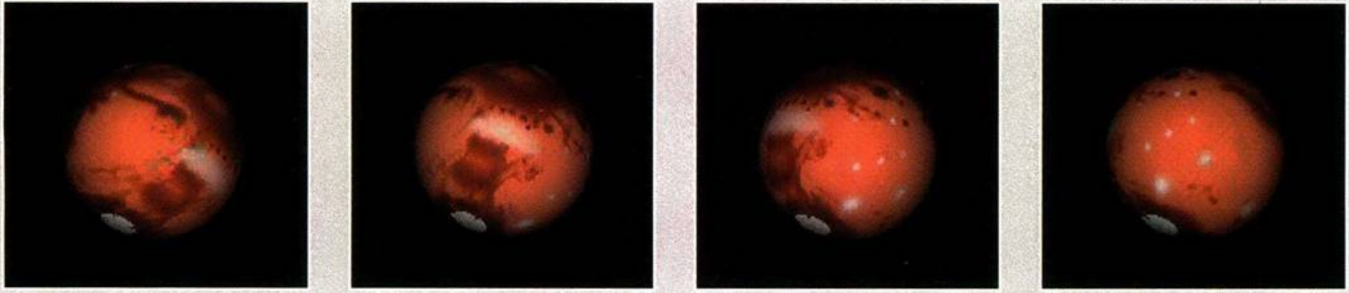
Spiral Galaxy NGC 488 in Pisces
Dale Mais
(14-inch f/7 Schmidt-Cassegrain reflector,
ST8 CCD camera, 20-minute exposure)



Galaxies NGC 7541 (left) and NGC 7537 in Pisces
Dale Mais
(14-inch f/7 Schmidt-Cassegrain reflector,
ST8 CCD camera, 20-minute exposure)



Comet Hale-Bopp in Scutum, July 20, 1996
Dan Schechter
(4-inch f/4.5 refractor, Scotchrome 400 film pushed to ISO 800, 30-minute exposure)

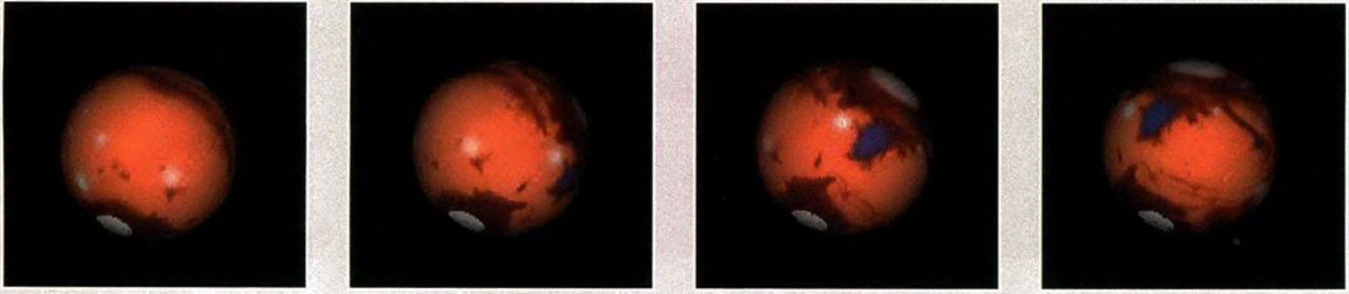


Central Meridian = 0°

Central Meridian = 45°

Central Meridian = 90°

Central Meridian = 135°



Central Meridian = 180°

Central Meridian = 225°

Central Meridian = 270°

Central Meridian = 315°

One Rotation of Mars, March 17, 1997
Daniel Troiani
Daniel Troiani created this computer illustration of what Mars might look like through a telescope on the day of its next opposition in March. To do this, he used detailed drawings submitted by observers to the Association of Lunar and Planetary Observers, an organization devoted to observing the planets, during the Red Planet's last opposition in 1995. Troiani produced his rendering in Adobe Photoshop.

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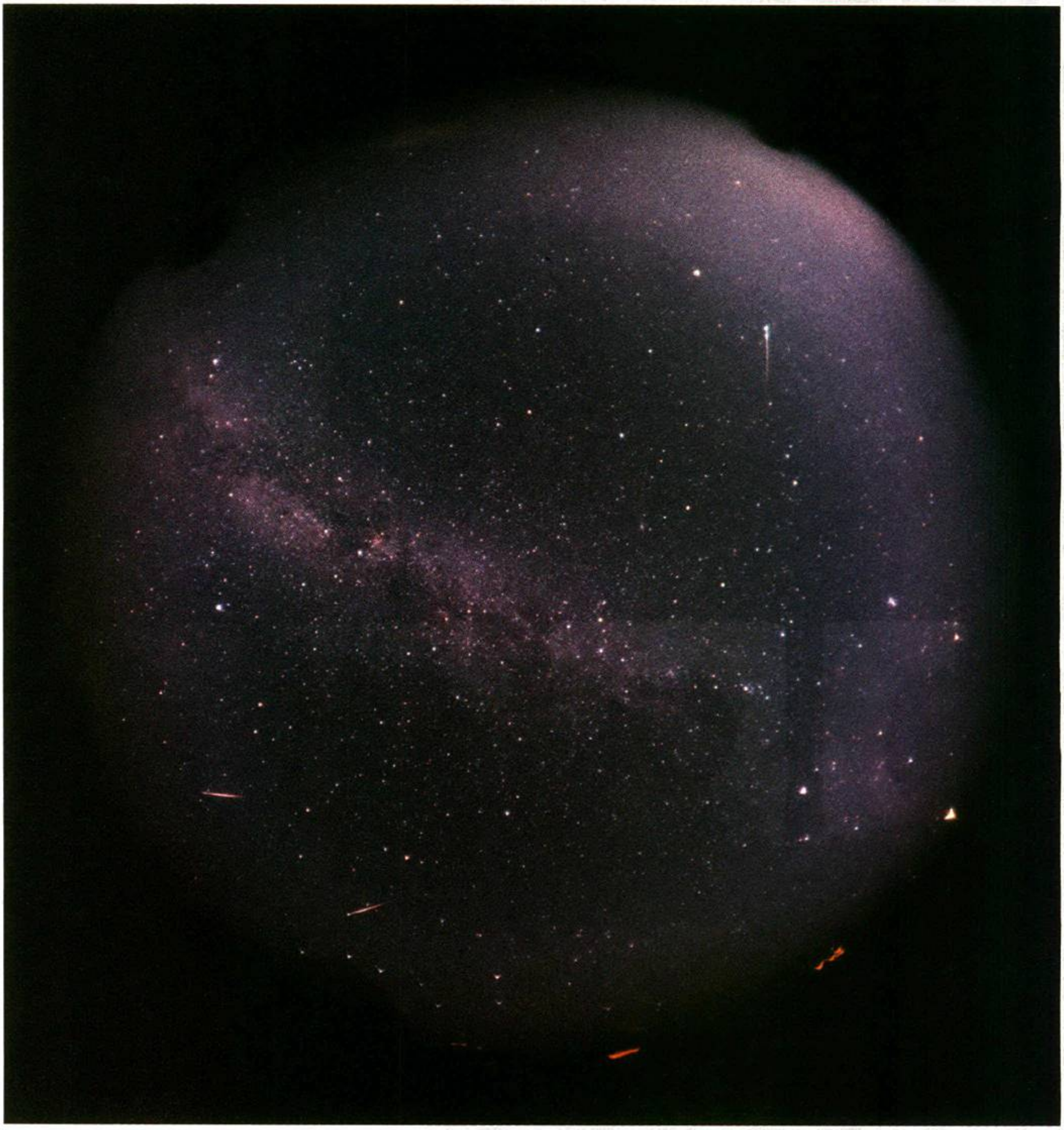

Fisheye View of the Perseid Meteor Shower

Michael Kobusch

(16mm lens at f/2.8, Agfachrome 1000RS film, 16-minute exposure)

1996's Perseid meteor shower put on a respectable show last August 12, with some European observers reporting a 100-meteor-an-hour spike around 8h UT (12 p.m. EDT). Earlier that morning, German astrophotographer Michael Kobusch captured three exceptional fireballs in this all-sky photo. "Several very bright meteors even lit up the ground and one left a persistent trail for about half a minute," he says.

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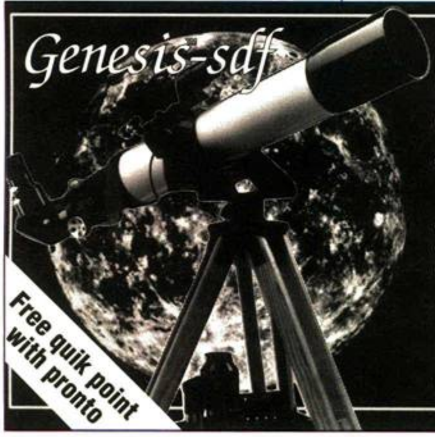

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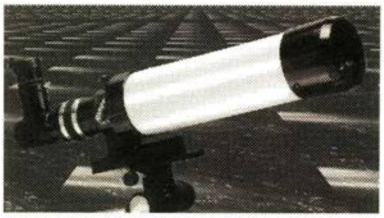

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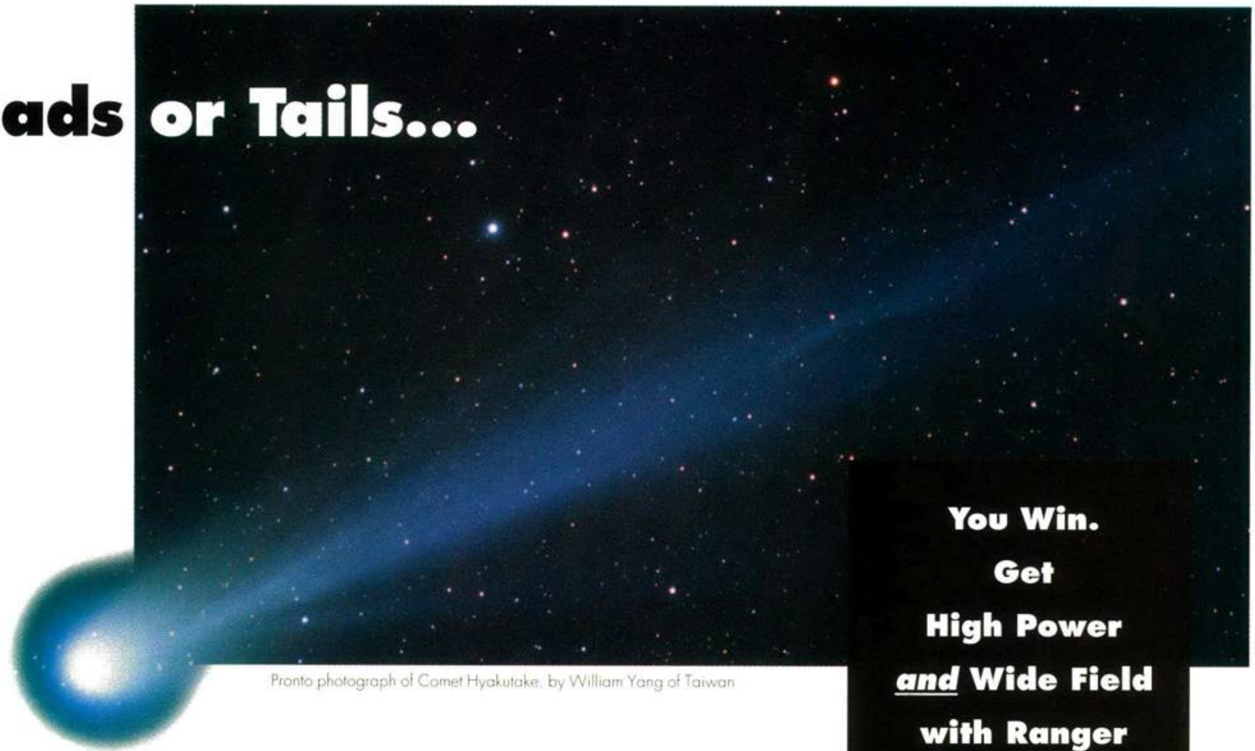

Pronto photograph of Comet Hyakutake, by William Yang of Taiwan

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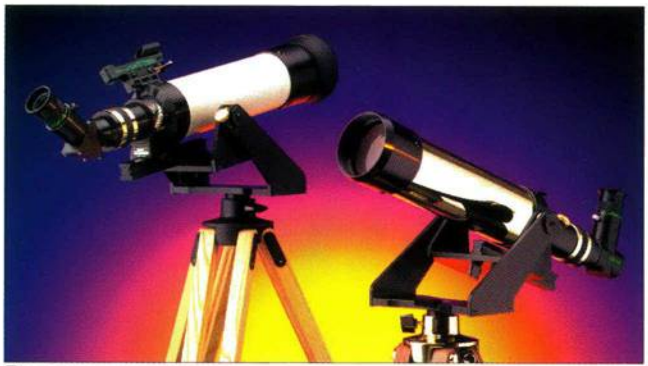
with Ranger
& Pronto.



Ranger

	Ranger	**Pronto**
Objective:	2-element, E.D.	Same
Power Range:	12x - over 200x	9x - over 200x
Visual Field:	3.3°	5.5°
Photo Field:	5.2° 35mm film diag.	Same
Aperture:	70mm	Same
Focal Length:	480mm	Same
Focal Ratio:	f/6.8	Same
Focus Type:	1¼", 2 Stage with Helical	2" Rack & Pinion
Dew Shield:	Available	Captive, Sliding
Mounting:	¼-20 Balance Bar	¼-20 Mount Ring
Carry Bag:	Available	Custom Padded
Choices:	1¼" Mirror Diag., 1¼" 45°, or Porro Prisms	2" or 1¼" Mirror Diags., 1¼" 45°, or Porro Prisms
Accessories:	All 1¼" Tele Vue eyepieces 2x Barlow optimum All Tele Vue Mounts Qwik-Point 35mm Camera Adapter Padded Shoulder Bag Padded Fitted Bag Rubber Lens Shade	All Tele Vue eyepieces All Tele Vue Barlows All Tele Vue Mounts Starbeam or Qwik-Point 35mm Camera Adapter Piggy-Cam

Pronto

- *I wanted an extremely portable instrument of superb quality. I consider Pronto to be the Questar of refractors. It is of superb manufacture and the views are razor sharp with beautiful contrast. — J.B. AZ*
- *I really like the RFT/diffraction limited design. And, Pronto was within budget. I'm very pleased! Not only could I see Io's shadow clearly transit Jupiter (at 95x), but I could trace Io itself across the planet's darker limb - even in front of a lighter band of clouds. Thanks again. — B.O. IL*
- *I'm impressed. Ranger performs like a larger aperture telescope. A star test revealed perfect diffraction patterns. — A.G. TX*
- *Great optics, great machining. Spectacular low-power views; seems much larger than 70mm; lots of detail on high power Jupiter. — P.R. NY*
- *I needed a grab and go scope with guts. Ranger is an astounding instrument! My 8" can't keep up with this rascal — N.R. NE*
- *I need portability; to carry on flights - (airline crew). Pronto is a beautiful scope; my first look at Jupiter and Saturn convinced me I had made the right choice. Thank You. — P.H. Hong Kong*

Product flyer free or send $3 for full-line literature.
Visit the Tele Vue web site at http://www.televue.com
Tele Vue Optics, Dept. A, 100 Route 59, Suffern, NY 10901, (914) 357-9522.

Tele Vue®

CELESTRON® REFRACTORS

Firstscope 80 EQ – The **best buy** in refracting telescopes – high performance and unbeatable price.

The **Firstscope 80 EQ** telescope is a good choice for the more serious beginning astronomer. An 80mm (3.1") aperture. The objective is an air-spaced achromat designed to yield the finest images available in this class of instrument. It has a 910mm focal length (f/11.4).

The equatorial mount is stable and includes setting circles in both axes as well as slow-motion cables in both axes for easy tracking. The wood tripod is adjustable in height and includes an accessory tray.

For astronomy you can enjoy breathtaking views of the Moon, Saturn with its ring structure, Jupiter and its belts and hundreds of deep-sky objects including galaxies, nebulae and star clusters. With a solar filter (optional) you can observe activity on the Sun. For terrestrial use, enjoy vistas from view homes or take your instrument out in the field to take advantage of our natural environment up close.

Standard accessories include a 6x30 Finderscope, 1¼" Focuser, 25mm SMA Eyepiece – 1¼" (36x), Star Diagonal – 1¼". Weight is 24 lbs.

4" REFRACTORS

Celestron offers two models of 102mm (4") equatorial refractor telescopes. These telescopes are for the more serious astronomer who appreciates superb optics and ultra-stable mounts.

The Great Polaris (GP) German equatorial mount is standard. Both axes have precision 144-tooth lapped worm gears for very smooth motion. The adjustable height, very rigid wood tripod has excellent vibration dampening characteristics and has a handy accessory tray.

The GP mount has a built-in illuminated polar alignment scope for fast polar alignment.

The premium optics of the **GP-C102** are made in Japan to rigid standards. It has a focal length of 1000mm (f/9.8). The **GP-C102-ED** model features Super ED glass to yield exquisite images of very high contrast and resolution with virtually no chromatic aberration. The ED unit has a focal length of 920mm (f/9) and has multi-coatings.

Standard accessories (the same on both models), include a 20mm Eyepiece – 1¼", 6x30 Finderscope with an 8° field and a Star Diagonal – 1¼". Weight is 39 lbs.

Optical tube assemblies of the 4" refractors are available separately and include tube rings, mounting plate and finderscope.

CELESTRON REFRACTING TELESCOPES:

The 60mm (2.4") refractor is the most popular telescope size for the beginning astronomy enthusiast or for casual gift-giving. It can introduce newcomers to the exciting hobby of astronomy at an affordable price.

FIRSTSCOPE 60

A 700mm focal length (f/11.7) telescope which contains all glass optical components with coated optics.

The glossy black telescope optical tube is made of aluminum. The sturdy altazimuth mount has a slow-motion control rod for vertical adjustments. The rigid, adjustable wood tripod includes an accessory tray.

Standard accessories include a 20mm H – .96" Eyepiece (35x), 6mm SR – .96" Eyepiece (117x), 2x Barlow Lens – .96", 5x24 Finderscope and a 90° Diagonal.

FIRSTSCOPE 60 DELUXE

The same as the Firstscope 60 except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25 SMA (28x) and 10mm SMA (70x).

Celestron offers two 60mm equatorial refractors – the Firstscope 60 EQ and the Firstscope 60 EQ Deluxe.

FIRSTSCOPE 60 EQ

Similar to the Firstscope 60 but the focal length for this telescope is 900mm (f/15).

Standard accessories include a 20mm H – .96" Eyepiece (45x), 12.5mm H – .96" Eyepiece (72x), 2x Barlow Lens – .96", 6x24 Finderscope and a 90° Diagonal. Weight is 11 lbs.

FIRSTSCOPE 60 EQ DELUXE

The same as the Firstscope 60 EQ except that all the .96" items are replaced with a **hybrid 1¼" diagonal and two 1¼" eyepieces** – 25mm SMA (36x) and 10mm SMA (90x).

The 1¼" accessories give you sharper images, a wider field of view and better eye relief. Weight is 11 lbs.

Celestron offers a premium grade 80mm (3.1") altazimuth refractor – **The Premium 80.** The premium built optics are made in Japan.

The Premium 80 is an ideal first telescope for the more serious beginning astronomer or terrestrial observer.

Its easy-to-use altazimuth mount includes slow-motion controls in both axes with flex cables allowing quick and easy pointing and tracking. The supplied attractive and very sturdy wood tripod is adjustable in height.

Standard accessories include a 26mm multi-coated Plössl – 1¼" Eyepiece (35x) for a wide field of 1.4°, high quality 6x30 Finderscope and a versatile 45° Erect Image Diagonal – 1¼". Weight is 18 lbs.

CELESTRON® *For more detailed information on these telescopes, contact a Celestron dealer or Celestron.*

Celestron International • 2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835